Merry Christmas

INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Devoted to Measurement and Control Problems

Vol. 3. No. 12 Pittsburgh, Pa. December, 1930

IN THIS ISSUE

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Handbook of Industrial Instruments
M. F. BÉHAR

The Position of Cathode Ray Instruments in the Field of Oscillography
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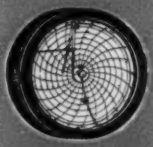
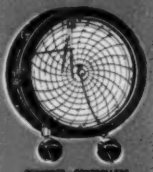
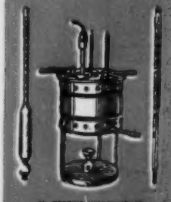
- Model 563 D. C. Circuit Tester
- New Model Micro-Metallograph
- Test Oscillator
- Type 561 Portable Resistance Tester
- The Promi Microscopic Drawing and Projection Apparatus
- New Recording Instruments

Place initials of interested persons in your organization opposite title and call it to their attention.

Happy New Year





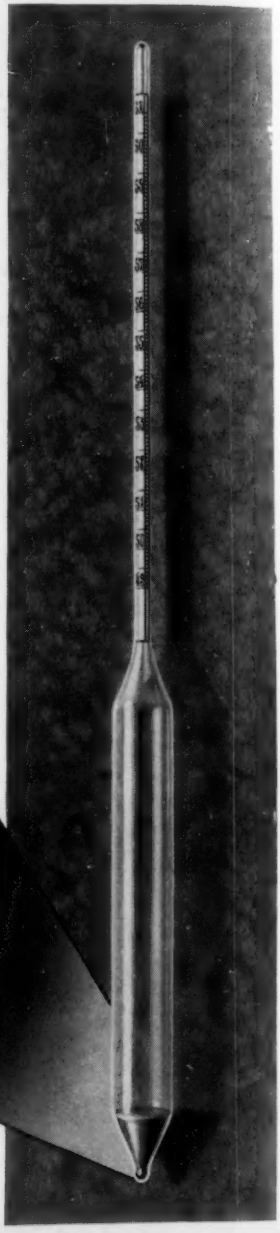


NU-TYP ~ A New TAG Hydrometer

TAG has designed a hydrometer with a streamline tip. No corners to collect dirt and no chance of it being pulled out of your hand in wiping.

Instead of the usual mercury ballast, a low melting point alloy has been firmly fastened in the bottom of the instrument so that it cannot come loose even when inverted. Every laboratory will appreciate the use of metal as ballast, for hydrometers will break and spilled mercury is dangerous.

The usual high standard of accuracy of TAG Hydrometers is maintained in this new instrument and its simplicity has made possible a 20% saving in price over the old type.



The illustration above shows graphically the structural features of the TAG NU-TYP Hydrometer.

C. J. TAGLIABUE MFG. CO.

PARK AND NOSTRAND AVE'S., BROOKLYN, N. Y.

Insist on Mercury Thermometers with the TAG-Hespe RED Reading Column

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for MEASURING RESISTANCE and MAKING CONTINUITY TESTS

To meet the growing demand for a low price portable ohmmeter for measuring circuit resistance and continuity, Weston now offers the double range Model 563 D.C. Circuit Tester. This new comer to the Weston line is accurate, compact, and rapid in operation. It is handsomely designed, thoroughly dependable and built to withstand hard service.

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Model 563 is a high sensitivity instrument, hence the drain on the self-contained 1.5 volt dry cell is exceedingly slight—on the high range, only 1 milliampere and on the low range, 10 milliamperes. On the high range the life of the cell is therefore practically its "shelf" life and assures long service before necessity of replacement. Write for Circular LL for more detailed information.

Weston Electrical Instrument Corporation

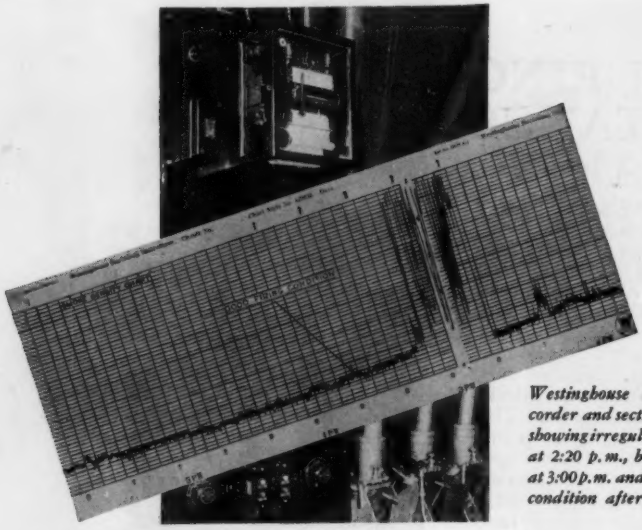
591 Frehlinghuysen Avenue, Newark, N. J.

Description of Model 563

Model 563 contains a standard high resistance Model 301 3¼" diameter meter and has two ranges of 5,000 and 50,000 ohms, a toggle switch for range selection, and a pair of 30 inch cables. A voltage adjuster on top of the instrument provides an easy means to compensate for any changes in potential of the self-contained 1.5 volt flashlight cell. The complete instrument weighs only two pounds.

MODEL 563
D. C. Circuit Tester

WESTON



Westinghouse Smoke Recorder and section of chart showing irregular coal feed at 2:20 p. m., blowing soot at 3:00 p. m. and good firing condition after 3:15 p. m.

Tells

COMBUSTION CONDITIONS

at a glance

THE Photo-electric Smoke Indicator and Recorder tells the operator at a glance the conditions of combustion in the form of smoke density. And it also makes a continuous record of these conditions.

Past methods have depended upon the human eye—inaccurate because weather conditions vary, and totally ineffective at night.

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Westinghouse

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Brown Model 801 Indicating Automatic Control Pyrometer

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Automatic Control

The new Brown Model 801 Indicating Pyrometer Controller illustrated can be supplied as an Automatic Control Pyrometer, Resistance Thermometer, Tachometer, or CO_2 Meter. This instrument has seven outstanding advantages. Write for detailed data on these seven important technical and practical operating features.

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Branches in 20 principal cities

Brown Automatic Control

To Measure is to Economize

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The Promi Microscopic Drawing and Projection Apparatus

Magnifies and projects specimens and samples on table or wall for drawing, examination and demonstration. Also used as a microscope and a microphotographic apparatus.

The Promi, recently perfected by a prominent German microscope works, is an ingenious yet simple apparatus, invaluable for scientific and industrial research, examination, comparison and recording. Can be used for inspection of raw materials, partly processed and finished products. Flaws easily overlooked by the naked eye are readily detected. Because of its simple construction the Promi can easily be handled by the Factory supervisor or foreman.

It has been endorsed by prominent engineers, scientists and educators, and is now in use in leading Universities, Colleges, industrial and research laboratories throughout the country.

The Promi apparatus is simple to set up and easy to manipulate. It swings readily from vertical to horizontal position on a swivel rod. It has a simplified illuminating system-strong filament bulb of low voltage, free from fluctuation and constant in intensity—advantages not possible with arc light illumination. The object stage is hollow for continual water cooling. Ocular and tube are furnished for high power magnification, and both objectives and eye pieces are of the standard microscope type. Rheostat can be used with both AC and DC current and for both 110 and 220 volts. It can be used in the ordinary lighted room for low power work. For drawing purposes in a dim room its magnification ranges up to 200 times, and for projection up to 1400 diameters at a distance of 6 feet.

AS A PROJECTION APPARATUS: Makes it possible for one or more persons to clearly and conveniently examine specimens and samples projected on a table or wall, eliminating the eyestrain and disadvantage of individual microscopic examination.

AS A DRAWING LAMP; Where a permanent record is desired a specimen is projected on paper enabling the enlarged image to be drawn in precise detail by simple tracing. (see illustration) Useful for enlarged drawing and designing. Higher magnification may be obtained by using tube and ocular and/ or high power objectives.

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AS A MICROPHOTOGRAPHIC APPARATUS: Microscopically enlarged specimens can be photographed witnout the use of a camera.

POLARIZER and ANALYZER: attachment can be supplied.

PRICE: F. O. B. New York **$100.00** complete apparatus in portable polished wood carrying case. Include extra bulb, rheostat for 110 and 220 volts with cords, plugs and switch for both DC and AC current, 11x objective, tube with 5x ocular, reflecting mirror and microcuvette tank. Extra equipment prices on request.

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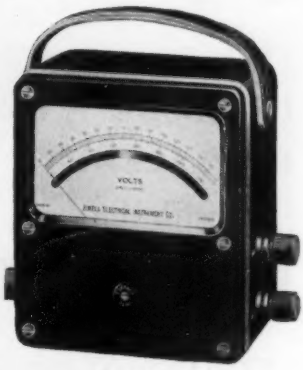
A Remarkable Line of Rugged Instruments

with a meter for every test



Do you use portable testing instruments?

If you do, consider carefully these advantages of Jewell Master Instruments.

1. ***All instruments are furnished in bakelite cases of uniform dimensions.***
2. ***Large scale openings are enclosed with non-shatterable glass.***
3. ***Movements are famous for accuracy and ability to withstand hardships of portable testing service.***

The Master Line includes Voltmeters, Ammeters, Wattmeters, Thermal Voltmeters, and VoltAmp Wattmeters for alternating and direct current. There is a meter for every test. Send for descriptive bulletin.

Jewell Electrical Instrument Co.

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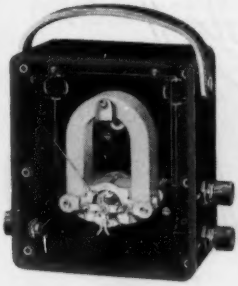
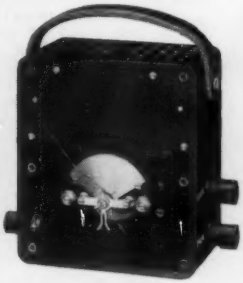
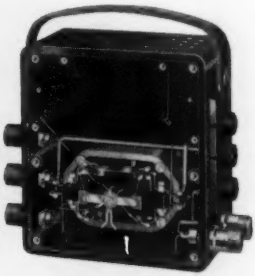


For direct current voltmeters and ammeters, the Jewell Style G Permanent Magnet Movement is used. The mechanical assembly is rigid, assuring stability of calibration. The rapid action and high damping speeds up all test jobs.



For alternating current voltmeters and ammeters, the Jewell Style D Iron Vane Movement is used. The damping chamber is of molded bakelite and highly efficient. The iron vane is riveted to the shaft to assure a permanent assembly.



For single and polyphase wattmeters, the Jewell Style L Dynamometer Movement is used. The vane box, supporting pillars, coil supports, and covers are of molded bakelite. The magnetic shield protects the instruments against external fields.

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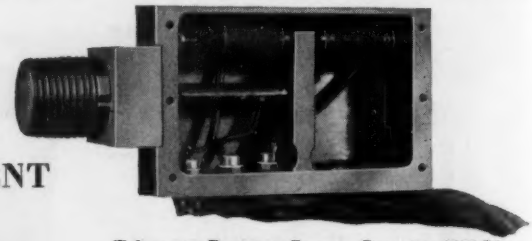

Telemeter Pressure Gauge—Capacity 2000 Lbs.

TRANSIENT stresses, vibratory phenomena, pressure surges and other variable forces are faithfully reproduced by the McCollum-Peters Electric Telemeter. This visible record is indispensable in studying the performance of mechanisms under actual working conditions. Any combination can be furnished for any purpose.

Telemeter Set, with special drum camera for high film speed, daylight loading. Calibrator at extreme left.

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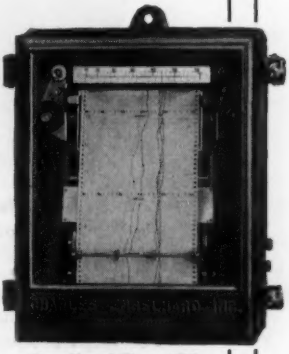

Engelhard Type "S" Recorder

Catalog describing the features of the Engelhard Pyrometer gladly mailed on request.

Cleveland Laboratories, Inc., 1988 East 66th St., Cleveland, Ohio; Exclusive Western and Mid-Western Engineer and Service Station.

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IMPROVED MULTIMETER

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Supplied in three separate combinations

1 microampere to 1 ampere (1,000,000 mics)

20 microvolts to 1000 volts

Just 3 Binding Posts and 1 Selector Switch

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For High Frequency Work, also with photo cells.

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Write for bulletins.

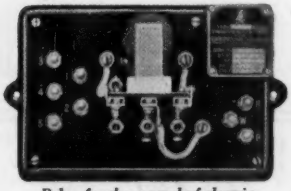
You only have to *Fall Down* once to prove It's CONTROL that PAYS

Just one slip. A mistake in reading pyrometer charts — an error in adjusting the valves — and the cost of the resulting product spoilage runs into real money. It is money that many manufacturers now save with Minneapolis-Honeywell controls applied to furnace, oven or kiln.

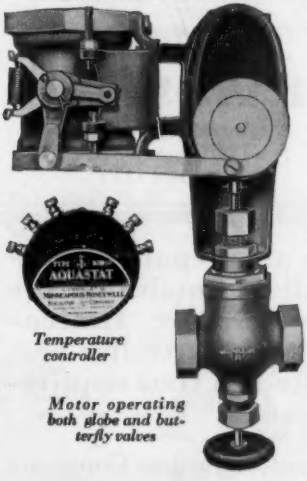
These controls earn their way in fuel savings, reduced supervision costs and greater product uniformity at the same time that they take the control job out of the hands of worried, hurried human beings.

Minneapolis-Honeywell motorized valves regulate the flow of steam, and proportion the flow of gas and air, or oil and air, in accordance with your process requirements. These valves operate with Minneapolis-Honeywell temperature controllers or with any pyrometric controller.

You incur no obligation by consulting with our engineers, and may discover a way to effect marked production economies in your plant.



Relay for the control of electric heaters, and of motor valves of large oil or gas fired furnaces



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Motor operating both globe and butterfly valves

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SPENCER Chemical Microscope
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Catalog M-39 features it.

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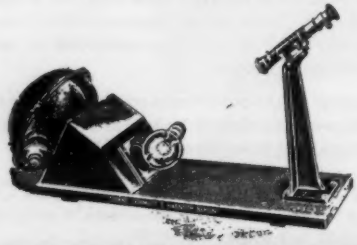

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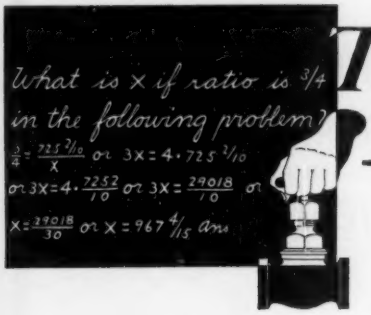
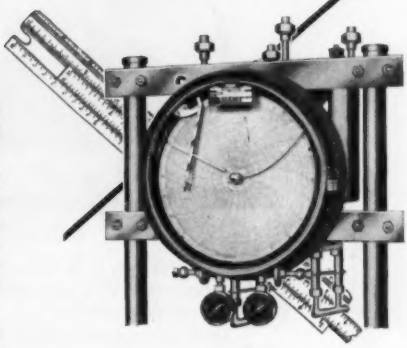

What is X if ratio is 3/4
in the following problem?
3/4 = 725 3/10 / X or 3X = 4 · 725 3/10
or 3X = 4 · 7252/10 or 3X = 29018/10 or
X = 29018/30 or X = 967 4/15 ans

THEN—THE HAND NOW—



The Slide Rule ended Long-Hand Computation of ratios. It saved time . . . it speeded production.

The Foxboro Ratio Flow Controller ends, just as definitely, all necessity of Hand-Valve Regulation in controlling the flow ratios of fluids. It does the job . . . better . . . quicker . . . with less effort . . . more accurately.

The Foxboro Ratio Control is especially designed for the various applications encountered in the Oil and Process Industries. It is built with an accuracy that is not disturbed even in the hardest service.

Investigate this dependable Foxboro Instrument today—it will pay you. Write to Dept. A. E.

FOXBORO RATIO FLOW CONTROLLER

Oil Refinery—controls ratio of Lean Oil to Rich Gas in an Absorption Plant; ratio of Steam to Fat Oil in the Steam Still. Power Plant, etc.—controls Ratio of Softener to Boiler Feed Water.

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Instruments for Controlling, Recording and Indicating Temperature, Flow, Humidity and Pressure.

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Dial 1000

and temperature stays there within 3°

With **POTENTIOMETER PYROMETERS**

Actual width of the L & N Chart is 9⅞ inches

SETTING an L & N Controller is as simple as setting a radio receiver. You adjust a dial, and get the temperature you want—automatically.

Dial, and you set robust cams within the L & N Potentiometer Pyrometer. These cams start and stop motor drives that control the fuel supply to furnace, kiln or lehr. Inside the big temperature-measuring machine itself an electric motor operates from your light circuit; drives cams and levers on substantial bearings, under sensitive control of the most accurate temperature-detecting circuit known to industry*.

This same motor also moves a pen which records the temperature clearly, on a chart 9⅞ inches wide—a chart easily readable to within 3° in 1000°.

L & N Catalog 84-I lists L & N Potentiometer Pyrometers for automatic temperature control. Catalog 87-I lists them for recording and for indicating. Special bulletins outline their application to various industries.

** Information as to the advantages of L & N Potentiometers will be sent on request.*

LEEDS & NORTHRUP COMPANY
4901 STENTON AVENUE PHILADELPHIA, PA.

LEEDS & NORTHRUP

P-209 Cleveland Chicago Houston Los Angeles San Francisco

Different Pyrometers—The Most Accurate Pyrometers In Industry
For Indicating, for Recording and for Controlling Automatically

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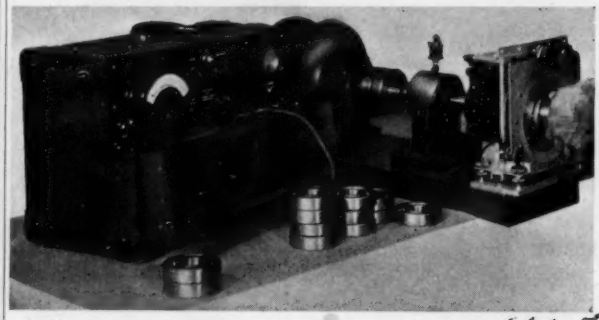
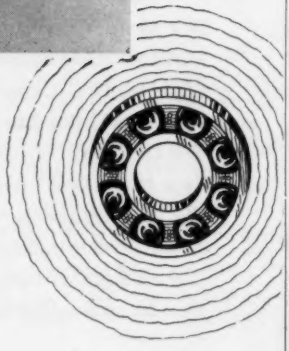
The New BURGESS BEARING TESTER



"Amplifies" vibrations to a surprisingly high degree, accurately showing variations in smoothness.



THE precision with which the best bearings operate, varies to a surprising degree—the exact amount of which can now be accurately measured by the new Burgess Bearing Tester.

The Burgess Bearing Tester is one of a group of Acoustimeters developed by the C. F. Burgess Laboratories, Inc., providing an accurate measurement of sound and vibration. They eliminate the guess-work always present in methods dependent upon the ear or sense of feeling.

One of these Acoustimeters is certain to help you. Write us about your sound or vibration measuring problems for our recommendations.

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HARRIS TRUST BUILDING CHICAGO, ILL.

Successor to the Standard Calorimeter Co.

INSTRUMENTS

INDUSTRIAL — SCIENTIFIC

(Reg. U. S. Pat. Off.)

Vol. 3, No. 12 DECEMBER, 1930 Pittsburgh, Pa.

To Our Readers

With this issue INSTRUMENTS completes its third year of service to the sciences and industries, to engineering and technical education. We have striven to made this service a useful one. The nature of this service is qualitatively summed up in the word *information*—the keynote struck in most of the commendations received from subscribers.

INSTRUMENTS thanks its friends, and wishes them all an *intensively* Merry Christmas and an *extensively* Happy New Year.

Why is it that the United States, which leads in the volume of production of instruments, in the number of their practical varieties and forms, in the extent of their laboratory and plant utilization, in the savings which they effect, lags behind Europe in the education of instrument designers and instrument-makers?

To show the high status of such education in Great Britain, one need only mention the courses of Prof. A. F. C. Pollard, Professor of Instrument Design at the Imperial College of Science and Technology.

Germany exhibits quantity as well as quality: Several schools list instrument design courses in their curricula.

Practical instrument-making is extensively taught in Europe but the divergences between the American and European theories of adolescent education and apprenticeship preclude drawing comparisons.

What of our own country? The picture is far from glorious in this regard: There is not one advanced instrument design course; and there appears to be only one instrument-making course. It is given at the Hebrew Technical Institute in New York City. Dr. Edgar S. Barney, the Principal, informs INSTRUMENTS: "So far as I know the Institute is the only educational institution giving a course of study and work in Instrument Making in this country." The school, founded in 1883, admits youths

of all races and creeds who "must be at least fourteen years of age, healthy and strong," of good character, etc. Tuition and tools are furnished free. The Instrument Making Course, two hours a day, elective in the senior year, covers—

> Theory and practice in the design and construction of electrical and scientific instruments and apparatus.
> Machining and finishing iron, brass, copper, hard rubber, and steel; gear cutting, fitting threads, boring, taper turning, grinding, polishing, making special tools.
> Constant use of the micrometer and similar accurate measuring instruments is required.
> Design and construction of complete pieces of apparatus.

All this is interesting. It shows that a start has been made. Our manufacturing readers will also appreciate the following:

> Experience shows that our graduates . . . advance more surely than can boys who have passed through years of regular apprenticeship to a particular trade, while their opportunities for general development have, meanwhile, been far greater . . . The School does not aim at teaching the higher branches of mechanical, civil, or electrical engineering. These studies, which are suited to older students, are amply provided for in the numerous polytechnic institutes and engineering schools of the vicinity . . . The Hebrew Technical Institute *does not especially attempt to prepare students for college.*

The italics are ours. This suggests (1) the need of intermediate instrument-making courses for older students, including production engineering, industrial management and advanced instrument design problems—probably two-year intensive courses. Also (2) the need for the establishment of an instrument design course in some one of our institutions of higher learning. The growing importance of the American instrument industry would seem to call for it. If not that, at least a research project at the Bureau of Standards, resulting in frequent pamphlets utilizable as texts.

We have been referring to a "need." Of this need there can be no question. Last month the Managing Editor, calling on a number of instrument manufacturers, was told of this need.

Manufacturers who have never heard of the *new* science of instrument design taught overseas cannot have considered its application. We mean the advanced design of instrument mechanisms as distinguished from either clockworks or machines—design which treats of degrees of freedom rather than power-efficiency. A fragmentary definition, to be sure, for the editors themselves have only gleaned meager imported fragments of that new science.

Nevertheless, these few glimpses reveal amazing possibilities, suggest a vision of American ingenuity and originality resting on sound fundamentals first laid down by patient European research. For example we submit that many American instruments might be improved by the application of the principles of minimization of variance expounded by Prof. Pollard in his Cantor Lectures. Many round-hole bearings, we dare say, could advantageously be replaced by vees; many expensive but troublesome male-and-female dovetail slides by cheaper and truer ball-and-race slides; many ordinary knife-edges by square edges on hardened balls so arranged as to permit a 90° angle of oscillation; many conventional tapped nuts by split nuts with threads cleared down to several contacting surfaces; many conical sockets by trihedral hollows. In every case interchangeability would be promoted; in many cases factory cost reduced.

Let instrument-making and instrument design urses be multiplied throughout our land, and the same American resourcefulness and engineering skill which has overcome the handicap of "learn-it-quick" education will soon achieve magnificent triumphs of new and improved instruments, will discover new methods of producing them in quantities, will confer untold benefits not only on the instrument manufacturers but on instrument-using American science and industry.

The Handbook of Industrial Instruments

M. F. Béhar*

CHAPTER X

Pressure Measurement

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1. Introductory Notes

Pressure is as universal a processing and working condition as temperature. Even where it is ignored, as on an assembly line, for instance, it exists in the form of atmospheric pressure. Artificial pressure has been an increasingly important factor in technical progress since the days of Papin, Newcomen, Watt and particularly Trevithick in England and Oliver Evans in America—these last two engineers being the first to employ high pressures deliberately. The effects of pressure on boiling and condensing points, reactions, etc., are of the utmost importance in many industries. Side by side with improvement in engineering materials for the efficient utilization of pressure in industry, refinements in such utilization have called for more and more reliable automatic control instruments and devices—and it is safe to assert that the bases of this progress have been and will continue to be improvements in measuring instruments accompanied by refinements in measurement technique.

Recent years have witnessed an amazing extension of the industrial pressure range in both directions, so that a thousand pounds per square inch and a ten-millionth of a pound per square inch (expressed otherwise, of course) are commonplace working pressures, indicated, recorded, and frequently even controlled by every-day instruments and apparatus. In mechanical engineering circles, high-pressure high-temperature work holds the floor; in the chemical industries, this new technology, according to *Chem & Met*, "has become the miracle worker . . . Older industries that have not yet felt the full effect of the new technology are threatened . . . far-reaching economic changes . . ."

The growing importance of vacuum work is also focussing the attention of a number of industries on the necessity for exact measurement and dependable control of absolute pressures too low for the manometers and gages of only a few years ago.

This industrial extension in the two directions of higher pressures and higher vacua imposes the necessity of referring in these chapters, at least briefly, to methods and instruments which have not quite passed from the laboratory to the plant. It would indeed be a disservice to the reader to confine the treatment strictly to the industrial pressure instruments

*Engineering Editor.

already on the market. Besides, there is no doubt that not many years will pass before some of the semi-industrial methods of pressure measurement which we shall mention will be realized in "regular stock" industrial instruments. Foreshadowing the industries of tomorrow, laboratory technique has achieved the measurement on the one hand of pressures three and even four times as high as those developed in long-range artillery, and on the other hand of absolute pressures so low that each molecule of gas travels on the average hundreds of feet back and forth in the bulb, without encountering another molecule. These achievements are mentioned in order to call attention to the interesting fact that the range of pressures measurable by instruments is 3.5×10^{14}. In other words, instruments have been developed to measure pressures three hundred and fifty million million times greater than pressures which other instruments have been designed to measure. Inasmuch as sensitivity and long scale ranges don't go together, the scale ratio of any one instrument seldom exceeds a thousand to one. That is to say, taking 1000 lb. per sq. in. range top as example, few individual instruments, accurate to ± 10 lb. per sq. in. at 1000 lb. per sq. in., are accurate to ± 0.01 lb. per sq. in. at 1 lb. per sq. in. It follows that "a full set of pressure gages" is somewhat of a rarity! It goes without saying, too, that the extreme high-pressure and high-vacuum gages are laboratory instruments or set-ups of apparatus, not designed for routine use by industrial plant engineers. In comparison, the measurement of industrial pressures is simple, and in point of fact the industrial instruments utilize only a few simple principles.

But danger lies in this very simplicity. Every pressure technician whom the author has met in the two years between the inception of this book and the date of writing this paragraph has urged that the descriptions of pressure instruments be preceded by copious data on the technique. "What's the good of these improved manometers if users don't improve their heads?" was one blunt remark that sticks in the memory. The fact is that the order of accuracy of pressure measurements now demanded in industry requires for its attainment better instruments (which are here) and better installations, better connections, better calculations, and all that is implied by the word "technique." It is in response to this acute need that sections 5 to 10 of this chapter are included. Much of the subject-matter of these sections is usually dealt with (when at all) in treatises on flow measurement, hydraulics, barometry, etc., and is not dealt with in the majority of the available discussions of pressure instruments. Example, the matter of pressure taps and connections. Just as a thermometer indicates the temperature of its bulb—which, if injudiciously located, may be much cooler (or hotter) than T_x, so does a pressure gage indicate the value of the force per area acting on *its* column, spring or other responsive element—which force is *never* of *exactly* the same value as P_x when the gage is at a distance from P_x. It is not merely a question of distance. Every engineer who has had occasion to measure the static pressure of a high-velocity fluid stream, for example, knows that the location, the direction, and even the shape of the edge of the hole in the pipe line or duct can produce a positive or negative error of, say, ten percent, whereas using a twenty-foot instead of a two-foot length of tubing between line and gage would introduce a negligible error.

While thus deliberately including here pressure measurement data usually considered under the measurement of fluid flow where it is of prime importance, it also has been deemed best to *omit*, from these chapters on

pressure, detailed descriptions of differential manometers which are designed, built and installed for flow measurement—in spite of the obvious fact that the direct function of such instruments is to measure pressure.

Another case in point is that of a liquid column, than which no industrial instrument is simpler: At first glance, the determination of the head requires only the linear measurement of the height of the column. Even conceding that the pressure supporting the column is equal to that which it is desired to measure, exactness of measurement, as called for nowadays, requires that corrections be made in the case of long columns. Hence Section 5.

As to Section 7 on "Dynamic Behavior," its inclusion was decided upon when the author was startled to find under a discussion of *open liquid columns for pressure measurement* in the most authoritative work of its kind in the English language, this amusing and astounding assertion:

> The inertia of a column of mercury is very considerable, so that it is not possible to obtain accurate readings while it is in motion.

which implies, "If you want to measure a pressure which fluctuates between 0.8 and 0.9 pounds per square inch, better use a three-foot glass tube to balance it with water, rather than a pocket-size mercury manometer—because the inertia of the mercury is greater than the inertia of the [equal weight of] water." Surely, it doesn't need Einstein's demonstration of the *identity* of the gravitational and inertial masses—their *equivalence* has long been known. The scientist who wrote the above did not realize that he was implying that a pound of mercury weighs more than a pound of water: What he had in mind (contextual inference) is the exasperating way some mercury columns keep on bouncing. What he should have said, but didn't, was that the oscillations of water are better damped because (1) the water column is 13.6 times as long, hence there is that much more area for skin friction, and (2) even with equal lengths, water wets glass and clings to it whereas mercury doesn't and slides on it almost frictionlessly. Or he may have been thinking of the mercury which is *not* measured—the mercury in a cistern or in the U bend.

"*Indicating, Recording and Controlling*"—In the field of pressure instruments, the recorders employ the same principles of measurement as the corresponding indicators. Outside of the glass manometers in which liquid level is observed visually, almost all classes are well represented on the market not only by indicating but by recording instruments. Moreover, should an engineer desire a pressure recorder of a class, type and range which is only represented by indicators, he has but to express his want to any of the several manufacturers of standardized electrical recording or remote-reading systems, and within a month or less he will be getting his daily pressure charts from a recorder which has easily been adapted to the pressure-responsive element of his selection. Therefore no separate treatment of pressure recorders is needed, and they will be dealt with together with the indicators in Chapter XI. On the other hand, there are sharp contrasts of function and differences of form between the measuring instruments and the controllers. These latter will therefore be dealt with in Chapter XII.

Instruments for Pressures Other Than Liquid or Gas—The original scheme of this Handbook did not contemplate describing such instruments, which were not considered to be industrial instruments and which were (and are) few in number of available types and makes. Recent develop-

ments in this line appear to be so interestingly fraught with possibilities for purely industrial applications, however, that some will be briefly described at the end of Chapter XI. This field of measurement is at present the subject of intense research, especially as regards "plastic flow," the entire concept of which is undergoing revision. Consequently there will be no references in this chapter to the theories of measurements of pressures of (or in) solid materials.

2. Definitions, etc.

Pressure is exactly defined as force applied to, or distributed over, a surface; and is measured as force per unit area. Although other technical meanings are sanctioned by general dictionaries, engineering terminology has purposely reserved other specific terms such as "stress," "weight," etc., in order to avoid confusion.

By a *Pressure Instrument* is usually meant one for the measurement of the pressure exerted by a fluid, a qualifying word or phrase being added for the exceptions. Example, a "soil pressure" indicator. It is an old saying in physics classrooms that pressure instruments measure a difference between two pressures, one usually being that of the atmosphere. Even in the case of the mercurial barometer, Diederichs and Andrae* call attention to the fact that the reading is the difference between atmospheric pressure and the vapor tension of the mercury in the air-free space at the top. That "*no* pressure-measuring instruments record pressure directly, but always as a difference between two pressures" is too general an assertion: Some gages record the *sum* of atmospheric and load pressures; and some high-vacuum instruments, such as absolute manometers, do not and cannot measure differentials.

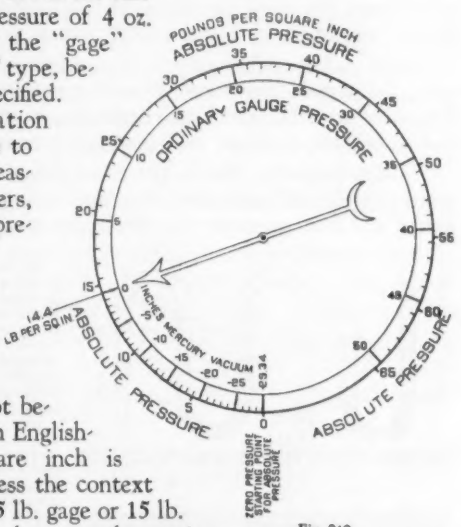
Absolute Pressure is actual total pressure, acting on a surface. Whatever unit is used the zero point is perfect vacuum. This term is used of necessity in engineering work to denote that the atmospheric pressure need not be added, or has been added. Addition is algebraic: For "a vacuum of two inches of mercury," when the corrected barometric reading is 29 inches, the value of the absolute pressure is 27 inches.

Absolute Pressure Gages are those which are not affected by barometric pressure in their indications of pressures to which applied. The simplest example is the closed-end U-tube. A barometer is an absolute pressure gage applied to the atmosphere and therefore measuring it only.

Gage Pressure is that which is indicated by open-end liquid column manometers and by Bourdon and other hollow spring and diaphragm gages. In all such instruments the measured pressure acts on one side, and the atmosphere on the other, of the pressure-responsive element. When such gages are not connected, the same pressure acts on both sides and they read zero: A gage reading zero in the open will still read zero if placed inside an evacuated vessel. Gages therefore indicate the difference between the absolute pressure to which they are connected and the atmospheric pressure around them. These things are no doubt familiar to the reader. What is sometimes overlooked is this: Should "two pounds gage" be maintained automatically in a piece of equipment while the barometric pressure is 14 lb. per sq. in., the absolute or actual processing pressure will be 16 lb. Should the barometric pressure rise or fall, the processing pressure will rise or fall correspondingly because the pressure-responsive

*Experimental Mechanical Engineering, Vol. I.

element of the usual automatic device is subjected internally to the controlled pressure and externally to the atmospheric pressure. Thus, except for rough work or in the case of pressures so high that barometric fluctuations are negligible, the corrected barometer reading must be added whenever the absolute pressure is the condition of importance. In many closed systems, however, the gage pressure is itself the important factor regardless of the barometric pressure. Thus in the case of gas to be supplied at a pressure of 4 oz. per sq. in., regulators are of the "gage" type and not of the "absolute" type, because 4 oz. *gage* pressure is specified.


POUNDS PER SQUARE INCH
ABSOLUTE PRESSURE
ORDINARY GAUGE PRESSURE
INCHES MERCURY VACUUM
14.4 LB PER SQ IN ABSOLUTE PRESSURE
ABSOLUTE PRESSURE
ZERO PRESSURE STARTING POINT FOR ABSOLUTE PRESSURE
Fig. 210

The unqualified designation *Pressure Gage* has thus come to refer to instruments which measure gage pressure. Some writers, however, make it a point to prefix "ordinary" or "common." The essential thing is to be specific not so much when referring to instruments as when referring to pressures. Thus "15 lb. pressure" is ambiguous—not because the area is not stated (in English-speaking countries the square inch is understood) but because, unless the context is explanatory, it may mean 15 lb. gage or 15 lb. absolute, the former having a value more than twice that of the latter. Fig. 210, from Westcott and Diehl's treatise on the measurement of gas and liquids, shows the relation of absolute and gage pressures for a barometric pressure of 14.4 lb.

Static Pressure is the force per unit area exerted on a wall by adjacent fluid which is at rest or which is *flowing parallel to the conduit wall.* Static pressure also exists in the midst of a body of fluid at a distance from a wall. For fluid at rest, or flowing in a conduit with parallel sides of sufficient length to insure parallel flow, static pressure is the same throughout each horizontal surface in the midst of the fluid as well as at any "static hole" (see Section 9) in the wall at this surface. Static pressure is also called Line Pressure in some branches of technical work.

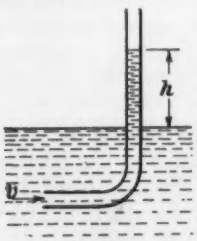


Fig. 211

Total Pressure or "Kinetic Pressure" is the sum of the static and impact pressures. It is greater than static pressure by an amount equivalent to the energy represented by the velocity of flow. It is exactly defined by the statement that frictionless, free expansion or isotropic expansion from fluid at rest with a pressure equal to the total pressure, into a region with pressure equal to the static pressure, will produce the existing velocity.

Impact Pressure or "Velocity Pressure" or "Velocity Head" is that due to the speed of flow. To remove all doubt from this concept, it is only necessary to think of the familiar manifestation in a shallow stream where some of the water, on meeting a

rock, "rises above its own level." If instead of a rock, a tube bent at right angle be held with the horizontal leg submerged and facing up-stream (Fig. 211) the surface of the water in the vertical leg will stand higher than that of the surrounding water. Obviously a pressure must exist to cause this difference of elevation. A useful memory-aid is that this velocity *head*, expressed in *feet*, is independent of the density of the fluid. Therefore, for an incompressible fluid, or for gas or steam flowing at low velocities, the Impact Pressure, expressed as the height of a column of fluid in feet, is numerically equal to the velocity head, $V^2/2g$. See Section 9.

Static and total pressures, as usually read, are gage pressures. However, the values used more often in engineering work are *Absolute Static Pressures* or *Absolute Total Pressures*, obtained by adding algebraically the barometric pressure and the gage pressure readings.

Head is defined as the height of a column or body of fluid above a given point considered as causing, counteracting or measuring pressure. So useful and convenient is the directness of this familiar term that systems

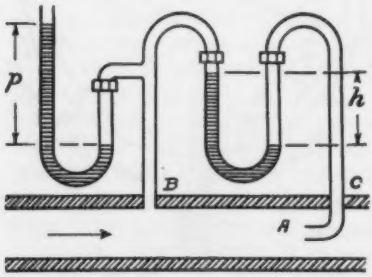


Fig. 212. Schematic diagram of a simple head meter installation for the measurement of static and impact pressures. The static gage pressure is taken off at static hole *B* and its value *p* measured by a U-tube with the other leg open to the atmosphere. In the U-tube between *B* and *C* the static pressure is counter-balanced by itself, hence, by means of the primary device *A* (representing an impact tube where the sum of static and impact pressures is exerted) the impact pressure is measured as the differential *h*.

In this case the differential head corresponds to the velocity head (at the particular point where *A* is located —speed being highest in center, lowest along wall of pipe). In other cases *h* is difference between static pressures taken off at two points between which there is a change of cross-section and hence a change of linear velocity.

of pressure units in terms of liquid head are employed in many lines of work, in preference to and often to the exclusion of systems resting on the exact basis of force per area. It is natural to say that a water wheel has been installed "at the foot of a dam where the average head is 20 ft.," or that "in boiler No. 2 we hold plus two-tenths of an inch in the pit and seven-tenths of an inch draft in the uptake." These illustrations give two reasons for the use of "head;" the utilization of hydrostatic pressure, and the measurement of pressure by liquid column instruments.

A *Head Meter*, however, is not a head gage, but a fluid meter consisting of (1) a primary device through which the stream of fluid produces a difference of pressure, and (2) an instrument which, responding to this differential head, indicates or records the rate of flow, or registers by integration the quantity of fluid. Another instrument, or a suitable second measuring element in the meter, measures the static pressure. Fig. 212 anticipates our chapters on flow measurement just enough to show the pressure measurements involved.

Differential. Specifically, in fluid meter work, the differential head produced through a primary device installed in the conduit for the purpose of flow measurement. Expressed in terms of head of the fluid itself, this differential depends only on velocity; expressed in head of water or mercury the differential depends also on the density of the measured fluid.

Differential Gages. From the above it is evident that the simplest U-tube may serve to measure fluid flow if it is provided with a square-root scale instead of the customary even linear divisions, *and if* it is con-

nected to the two sides of a differential producer. Some glass U-tubes with fittings and accessories, not including differential producers, are listed as "flow meters" in many catalogs. But the distinction may be pointed out that whereas the measuring instruments of all head meters are differential pressure gages, a differential gage, *by itself*, is not a flow meter.

Hydrostatic Pressure is that due to head of liquid. Its value P at a distance h from the surface of a fluid of density is hdg, g being the gravitational constant and the same system of units being used.

Pressure Base and *Base Pressure*. Since the actual quantity of any gas supplied or utilized varies not only with its volume but with its absolute pressure and inversely as its absolute temperature, a Pressure Base (usually expressed in oz. per sq. in.) must be specified. Calculations are made by adding the pressure base to the atmospheric pressure, the value of which must also be specified. Westcott and Diehl* give pressure base multiplier tables for eight bases and for both 14.4 and 14.7 lb. per sq. in. values of atmospheric pressure.

Critical Pressure is that pressure under which a substance may exist as a gas in equilibrium with the liquid at the Critical Temperature, which is that temperature above which a gas cannot be liquified by pressure alone.

"Solid" Pressures. In some cases it is not force per area but total pressure which is understood and measured, as with cutting-tools. In others it is more exactly the *Stress*, or force producing or tending to produce deformation in the body measured by the force applied per unit area.

Mano-. This prefix comes from the Greek root *manos*, thin or rare; which explains the derivation of *manometer* as meaning exactly an instrument for measuring gas pressure.

Piezo—Greek for pressure. A piezometer is a pressure-measuring instrument but this designation is reserved for special gages and apparatus. A *Piezometer Ring* is a ring-shaped pressure chamber around a straight, smooth pipe section and communicating therewith by a number of uniformly spaced similar holes normal to the conduit wall. *Piezometry* is specifically the measurement of the compressibility of liquids. *Piezoelectricity* deals particularly with those crystals which alter in size and shape in electric fields and, conversely, develop electrical charges on their faces when mechanically strained, so that they can be utilized to measure rapidly changing pressures.

Vacuum. 1. The zero point of absolute pressure scales. 2. Negative pressure, below atmospheric; as "10 inches of vacuum."

Viscosity, in its various effects on pressure and in pressure instruments, may simply be defined as resistance to change of form.

3. Pressure Units and Their Conversion

Four systems of units are in use: (1) Absolute units of force; (2) Gravitational units of force; (3) Linear units of liquid head; (4) Atmospheres. The first and fourth systems being very seldom employed for industrial pressure measurements in America, it is usual to say that pressure is expressed either in weight units per unit area, or in liquid head.

The relation between gravitational and absolute units of force hinges entirely on the value of g, the acceleration due to gravity. Gravitational units are g times absolute units. For English units g is substituted in ft. per sec.^{2}, hence one pound weight equals roughly,

*Measurement of Gas and Liquids by Orifice Meter, published by Metric Metal Works (American Meter Company).

TABLE VIII—PRESSURE UNIT CONVERSION—To 5 or 6 significant figures. Arranged by M. F. Béhar from latest values data supplied by N. E. Dorsey, Bureau of Standards, Nov. 25, 1930.

		lb./in.²	oz./in.²	lb./ft.²	ton/in.²	ton/ft.²	in.H_2O	ft.H_2O	in. Hg.	A_n	dyne/cm.²	g/cm.²	kg./cm.²	cm. H_2O	m. H_2O	mm. Hg.	μ Hg.
ENGLISH	1 Pound /sq. in. =	*1.0000*	16.000	144.00	5.0000 x10^{-4}	7.2000 x10^{-2}	27.680	2.3067	2.0360	6.8045 x10^{-2}	68947.	70.306	7.0306 x10^{-2}	70.308	0.7031	51.715	51715.
	1 Ounce /sq. in. =	0.0625	*1.0000*	9.0000	3.1250 x10^{-5}	4.5000 x10^{-3}	1.7300	0.1442	0.1272	4.2528 x10^{-3}	4309.2	4.3941	4.3941 x10^{-3}	4.3942	4.3942 x10^{-2}	3.2322	3232.2
	1 Pound /sq. ft. =	6.9445 x10^{-3}	0.11111	*1.0000*	3.4723 x10^{-6}	5.0000 x10^{-4}	0.19223	1.6019 x10^{-2}	1.4139 x10^{-2}	4.7254 x10^{-4}	478.80	0.4882	4.8824 x10^{-4}	0.4882	4.8825 x10^{-3}	0.3591	359.13
	1 Ton /sq. in. =	2000.0	32000.	2.8800 x10^{5}	*1.0000*	144.00	55361.	4613.4	4072.0	136.09	1.3789 x10^{8}	1.4061 x10^{5}	140.61	1.4062 x10^{5}	1406.2	1.0343 x10^{5}	1.0343 x10^{8}
	1 Ton /sq. ft. =	13.889	222.22	2000.0	6.9445 x10^{-3}	*1.0000*	384.45	32.038	28.278	0.9451	9.5760 x10^{5}	976.48	0.9765	976.51	9.7651	718.26	7.1826 x10^{-5}
	1 Inch water 39°F. =	3.6127 x10^{-2}	0.5780	5.2022	1.8063 x10^{-5}	2.6011 x10^{-3}	*1.0000*	8.3333 x10^{-2}	7.3554 x10^{-2}	2.4582 x10^{-3}	2490.8	2.5399	2.5399 x10^{-3}	2.5400	2.5400 x10^{-2}	1.8683	1868.3
	1 Foot water 39°F. =	0.43352	6.9363	62.427	2.1676 x10^{-4}	3.1213 x10^{-2}	12.000	*1.0000*	0.8826	2.9499 x10^{-2}	29890.	30.479	3.0479 x10^{-2}	30.480	0.3048	22.419	22419.
	1 In mercury 32°F. =	0.49116	7.8586	70.727	2.4558 x10^{-4}	3.5363 x10^{-2}	13.596	1.1330	*1.0000*	3.3421 x10^{-2}	33864.	34.532	3.4532 x10^{-2}	34.532	0.3453	25.400	25400.
INT'L	1 Normal Atm'ere =	14.696	235.14	2116.2	7.3480 x10^{-3}	1.0581	406.79	33.900	29.921	*1.0000*	1.0132 x10^{6}	1033.2	1.0332	1033.3	10.333	760.00	7.6000 x10^{-5}
	1 Dyne/sq. cm. . } =	1.4504 x10^{-5}	2.3206 x10^{-4}	2.0886 x10^{-3}	7.2519 x10^{-9}	1.0443 x10^{-6}	4.0147 x10^{-4}	3.3456 x10^{-5}	2.9530 x10^{-5}	9.8692 x10^{-7}	*1.0000*	1.0197 x10^{-3}	1.0197 x10^{-6}	1.0197 x10^{-3}	1.0197 x10^{-5}	7.5006 x10^{-4}	0.7501
	1 Microbar . . }																
METRIC	1 Gram /sq. cm. =	1.4224 x10^{-2}	0.2276	2.0482	7.1117 x10^{-6}	1.0241 x10^{-3}	0.3937	3.2809 x10^{-2}	2.8959 x10^{-2}	9.6784 x10^{-4}	980.66	*1.0000*	0.0010	1.00003	1.00003 x10^{-2}	0.7356	7355.6
	1 Kilogram/sq. cm. =	14.224	227.58	2048.2	7.1117 x10^{-3}	1.0241	393.71	32.809	28.959	0.9678	9.8066 x10^{5}	1000.0	*1.0000*	1000.03	10.0003	735.56	7.3556 x10^{-5}
	1 Cm. water at 4°C. =	1.4223 x10^{-2}	0.2276	2.0481	7.1115 x10^{-6}	1.0240 x10^{-3}	0.3937	3.2808 x10^{-2}	2.8958 x10^{-2}	9.6781 x10^{-4}	980.64	0.99997	9.9997 x10^{-4}	*1.0000*	0.0100	0.7355	735.54
	1 Meter water 4°C. =	1.4223	22.757	204.81	7.1116 x10^{-4}	0.1024	39.370	3.2808	2.8958	9.6781 x10^{-2}	98064.	99.997	9.9997 x10^{-2}	100.00	*1.0000*	73.554	73554.
	1 Mm. Hg. at 0°C. =	1.9337 x10^{-2}	0.3094	2.7845	9.6684 x10^{-6}	1.3922 x10^{-3}	0.53525	4.4605 x10^{-2}	3.9370 x10^{-2}	1.3158 x10^{-3}	1333.2	1.3595	1.3595 x10^{-3}	1.3595	1.3595 x10^{-2}	*1.0000*	1000.0
	1 Micron Hg. 0°C. =	1.9337 x10^{-5}	3.0939 x10^{-4}	2.7845 x10^{-3}	9.6684 x10^{-9}	1.3922 x10^{-6}	5.3525 x10^{-4}	4.4605 x10^{-5}	3.9370 x10^{-5}	1.3158 x10^{-6}	1.3332	1.3595 x10^{-3}	1.3595 x10^{-6}	1.3595 x10^{-3}	1.3595 x10^{-5}	0.0010	*1.0000*

32.3 poundals. For metric units, substituting the value of g in cm. per sec.^{2}, one gram weight equals, roughly, 981 dynes.

English weight units are used in connection with English units of area; and the same for metric. There is no necessity for hybrid pressure units such as pounds per square meter or grams per square inch. The whole situation is complicated enough as it is.

The usual English weight unit is the pound. Ounces and tons are less frequently used, the former in the gas industry on account of its convenience. The usual English unit of area is the square inch, but the square foot is sometimes used in civil engineering, etc. Already we have six English pressure units; but the *pound per square inch* is used more frequently than all other five added together, and is the recognized pressure unit in all branches of engineering.

Both the gram and the kilogram are commonly used as metric weight units, the centigram and decigram almost never; both the square centimeter and the square meter as area units, especially the former—the square millimeter seldom and square decimeter almost never. The number of different pressure units matters less, conversion being simply a matter of shifting the decimal point.

The liquid head system possesses obvious advantages, but is somewhat complicated by the number of linear units, combined with the necessity of naming the liquid and, for accurate work, of taking into account its temperature, and the value of g at the latitude and elevation. Fortunately, while liquids other than water and mercury are employed in actual manometers, only these two are used as measures. But the custom of reducing mercury head to the ice-point clashes with the obvious impossibility of doing so for water head—water columns being considered standard, for exact work, at the temperature of maximum density which is 3.9°C. or 39°F., and "standard," in various calculations, at 62°F. (See Section 5). Reduction to standard conditions being only necessary for exact work, the liquid head system is deservedly widespread. In metric units, conversion of standard water head to force per area is, of course, convenient.

The absolute unit of force is the dyne, and pressures are expressed in dynes per sq. cm. in scientific work, and also in engineering work on low pressures, for which this unit (close to 1 μ Hg) is convenient. The dyne per sq. cm. is not used at all in regular industrial production work, to the author's knowledge. The bar is the absolute unit which would be easiest to work with in industry as its value is close to that of the normal atmosphere. By definition it is equal to one million dynes per sq. cm.

Lastly, the Normal Atmosphere, an international unit. Its value is very close to one million dynes per sq cm., and since it roughly equals also ten meters water head, or 1 kg. per sq. cm.—which takes much longer to say or write in any language—it is growing in acceptance in America, though its spread here cannot compare with the universality of its employment in France (where it originated) and in many other countries.

Table VIII, prepared with the assistance of the Bureau of Standards, especially for this Handbook, gives conversion factors for sixteen pressure units. Conversion tables hitherto published have never, it is believed, exceeded eight pressure units—no doubt on account of typographic difficulties; so that this table contains more than four times the number of factors previously given on one page (16×15 as compared with 8×7).

The conversion chart on the next page should also prove handy.

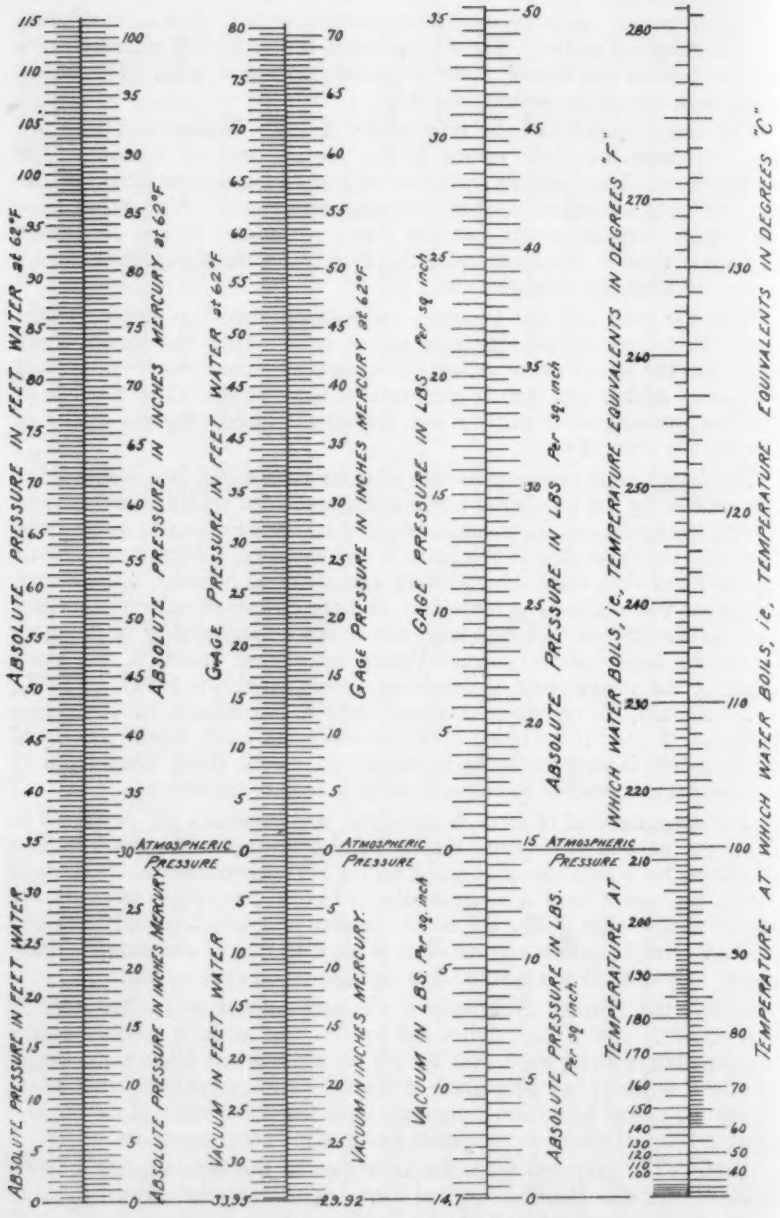

ABSOLUTE PRESSURE IN FEET WATER at 62°F
ABSOLUTE PRESSURE IN INCHES MERCURY at 62°F
ATMOSPHERIC PRESSURE
ABSOLUTE PRESSURE IN FEET WATER
ABSOLUTE PRESSURE IN INCHES MERCURY
33.95
GAGE PRESSURE IN FEET WATER at 62°F
GAGE PRESSURE IN INCHES MERCURY at 62°F
ATMOSPHERIC PRESSURE
VACUUM IN FEET WATER
VACUUM IN INCHES MERCURY
29.92
GAGE PRESSURE IN LBS Per sq. inch
ATMOSPHERIC PRESSURE
VACUUM IN LBS. Per sq. inch
14.7
ABSOLUTE PRESSURE IN LBS Per sq. inch
15 ATMOSPHERIC PRESSURE
ABSOLUTE PRESSURE IN LBS. Per sq. inch
0
TEMPERATURE AT WHICH WATER BOILS, i.e. TEMPERATURE EQUIVALENTS IN DEGREES "F"
TEMPERATURE AT WHICH WATER BOILS, i.e. TEMPERATURE EQUIVALENTS IN DEGREES "C"

Fig. 213. The "TAG Pressure Vacuum Temperature Equivalents Chart." To convert from one scale to another lay a rule horizontally across the chart. The chart is based on the following values: 1 lb. per sq. in. = 2.0416 in. of mercury at 60°F = 2.309 ft. of water at 62°F.; 1 ft. of water at 62°F = 0.433 lbs. per sq. in.; 1 in. of mercury at 62?F = 0.491 lb. per sq. in = 1.134 ft. of water at 62°F.; specific gravity of mercury = 13.58 at 60°F. (*C. J. Tagliabue Mfg. Co.*)

4. General Classifications of Pressure Measuring Instruments

Only brief general classifications need be given at this point. Details belong in the descriptive chapter (XI) which follows.

The Scientific Classification by Principles Employed

According to the principles which they utilize, all pressure measuring instruments may be divided into two distinct groups: the primary manometers, any one of which can be constructed and calibrated without reference to another pressure-measuring instrument; and the secondary instruments, that is to say all others, regardless of principle, method, range or form. A gage belonging to the second class can only be calibrated by comparison. It goes without saying that this established division has no bearing on the intrinsic accuracy of individual instruments in each group.

Another broad classification on scientific lines is: (1) Manometers which depend upon gravitational forces for their indication of the measured pressure, and (2) all others.

Primary Manometers—The great majority of these instruments take the forms of single or multiple glass tubes in which a column of liquid is supported by the pressure to be measured, the determination of which is then a matter of measuring the exact height of the visible column and applying a density correction factor when necessary. The result is the value of the measured pressure in units of liquid head. There are several modifications, including inclined tubes, precision manometers, multiple and compound-column types, etc. Another class of primary instruments takes in the various forms of the closed-column or compression manometer, in which the measured pressure acts upon a body of gas whose exact initial volume (at, say, 750 mm. Hg. and 290°Abs.) is known and whose reduced (or greater) volume can be measured exactly. In this case it is necessary, after a considerable change of pressure, to wait until the temperature of the compressed gas falls (or rises) to the initial point, or to correct for temperature differential by Charles' Law, or to use a constant-temperature bath. The measurement of pressure is then a matter of applying Boyle's Law. The usual form consists essentially of a sturdy glass tube with a graduated closed end. Hydrogen is preferably employed because, outside of its departure from Boyle's Law which is easy to allow for in the calibration, it behaves as a perfect gas within the ranges of the manometers. Mercury is used to transmit the pressure because other liquids would absorb and contaminate the hydrogen (mercury vapor correction is negligible). A portion of the mercury usually acts as a positive or negative head but this is easy to measure and add or subtract. The barometer reading is added to obtain gage pressure.

The McLeod "Gage" is a variant, for vacuum work, of the compression manometer, in which a sample of the air or gas, whose pressure is unknown, is admitted without change of pressure into a measuring chamber and an exact volume then sealed off by mercury, after which a known pressure (mercury head, using the same supply) compresses the air or gas into the graduated capillary top of the measuring chamber. Temperature precautions being observed, the original pressure is that fraction of the measured final pressure corresponding to the reciprocal of the volume ratio, plus or minus a correction for departure from Boyle's Law when exact values are desired.

Primary Pressure Gages—The usual form consists essentially of a vertica l cylinder into which fits a piston which can be loaded with weights. The

clearance is usually that of a sliding fit so that the piston and cylinder areas can be considered equal. The measured force is composed of the weight of the piston and its attached plate or other device, plus the weights which are added, and the atmospheric pressure on the piston area. This last component can usually be omitted in the computation which is then a matter of dividing the exactly-known total weight by the exactly-known area, thus obtaining the value in engineering pressure units. Friction itself is nearly eliminated by the use of oil for transmitting the measured pressure, and its effects on the determination are altogether eliminated by rotating the piston and set of weights ("spinning the plate"). The instrument just described is the dead-weight gage for measuring an unknown pressure, but this general type is mostly used for *applying known* pressures in order to calibrate spring gages. As thus modified it is the familiar gage tester. See Chapter XI.

Liquid Column and Plunger Combination.—Disregarding the contrary opinion of extant scientific treatises, we do not hesitate to include these instruments in the "primary" group. The principle is that of the piston-and-cylinder, combined with that of the liquid column. The measured pressure is applied under a small piston rigidly connected to a larger one which expels mercury up a glass tube. The two pistons, as an assembly, may be called a differential plunger. The upper or larger piston supports a known head of mercury—corresponding to the weights on the plate of a gage tester. The total force is exerted on the area of the smaller piston. The ratio of the piston areas being known, the measured pressure is the mercury head times this ratio and such instruments meet, in principle, the definition of "primary." As actually constructed, since friction elimination cannot be attained by rotation, it is practically achieved by the use of sealing diaphragms, loose fits of pistons in their cylinders, and a maximum up-and-down plunger movement of 0.02 in. for maximum and zero heights of mercury. It is no doubt on account of these features of actual construction that such instruments are not considered "primary" in the strict sense.

Liquid-Sealed Bells—This principle is likewise "primary" when the pressure is balanced by weights (usually pendulums) and not by springs. In some actual industrial instruments however, there enter other factors which, while they are in the nature of refinements and conveniences, debar them from admittance to the scientific primary group. The same holds true with regard to

"Ring" and "Tilting" Manometers which are primary in principle but actually embody construction features which, while of distinct industrial value, preclude independent calibration.

"Secondary" Gages—This designation is given here because it is the accepted generic name for all pressure instruments which require calibration by comparison with those of the primary group, but we shall not use it again outside of this present discussion. The fact is that most industrial pressure measuring instruments belong to this group and the author is convinced that standardization of materials, of dimensions, of heat treatments, etc., has resulted in the availability of individual instruments which can be relief upon to measure pressures with a degree of accuracy in excess of that required in the most rigid specifications. A brief outline of some of the principles employed in "secondary" gages now follows:

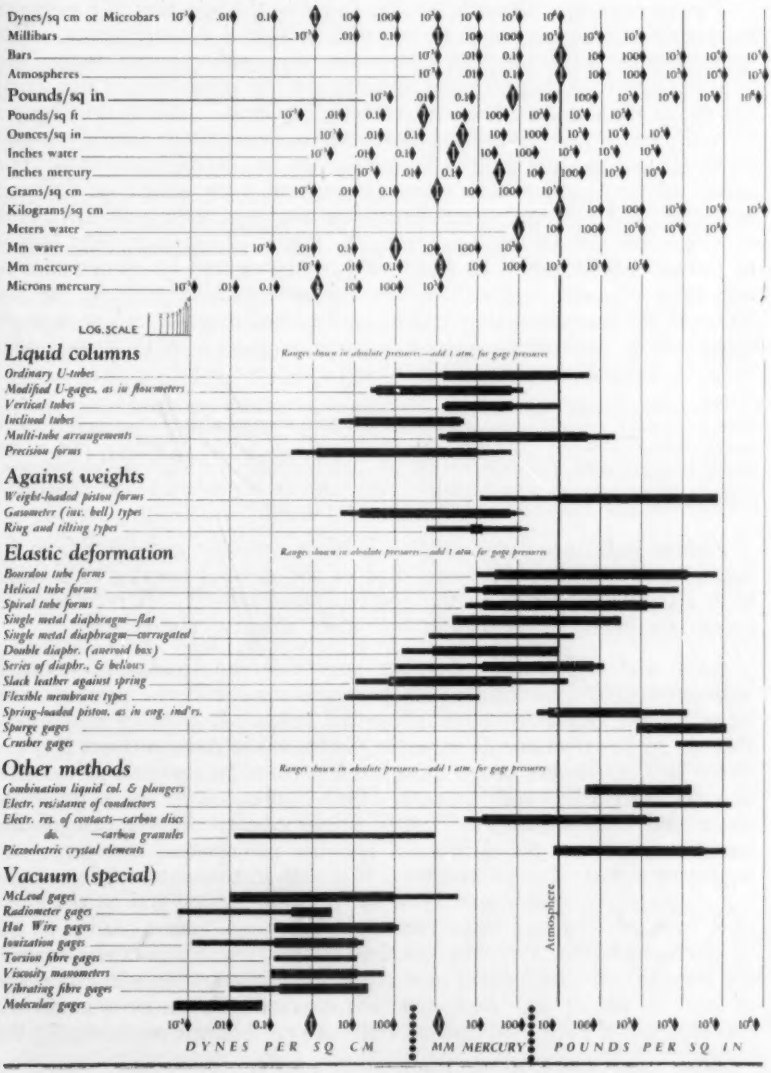
Elastic Deformation—Steel, brass, bronze and other metals are mostly employed for pressure-balancing springs which may be divided into (1) diaphragms; (2) hollow springs such as Bourdon tubes, helical tubes, capsular springs, etc.; and (3) separate or "replaceable" springs used in connection with "slack" diaphragms, bellows, etc., as well as with pistons. The great variety precludes even brief descriptions. See Chapter XI.

TABLE IX—PRESSURE MEASURING INSTRUMENTS

Classes & Types, and Ranges of Applicability

Chart of Orders of Magnitude of Pressure Units

Notes—(1) Graphic pressure scale is logarithmic: each vertical line denotes ten times the value of the line at its left. (2) Scales of units extend only over pressures with which they are ordinarily used. (3) Ranges shown opposite types of instruments are those within which such types can be employed for measurement. Heavy portions indicate agreement of sources of information as to suitability. Lighter portions extend over pressures for which such suitability (or the availability of instruments) has been questioned.



Other Methods—Electrical resistance is employed in two ways: (1) contact resistance, as in practical carbon disc cells used in industry, and (2) resistance of conductors such as manganin wires, mercury in non-conducting tubes, etc. Electrical conductivity of gases, capacity of piezo-electric crystals, gas viscosity (for vacuum work) and permanent deformation as in crusher gages for explosion maximum pressures, are among the other principles utilizable for pressure measurements. Some of the instruments will be described in Chapter XI, with emphasis on the practical industrial forms.

Industrial Classifications

The application is the determining factor in the selection of a pressure measuring instrument, as it is in other industrial measurements. The most obvious classification of applications is according to the range, and in most cases only the maximum pressure need be considered in specifying the top of the scale, the bottom usually being "zero." Along this line we have in general four divisions of instruments, respectively for (1) vacuum work, (2) low pressures, (3) medium pressures and (4) high pressures. The numerical meanings of these four designations vary widely in different industries and also with such factors as new engineering developments causing a revision of the conception of "high." Moreover, most classes of instruments (classified by principle) are represented by numerous constructions whereby each class covers the low, medium and high ranges. Example, the Bourdon spring, which is to be found in sensitive low-pressure gages and in extremely rugged high-pressure gages. With these things in mind, Table IX has been prepared as a rough but handy guide.

This table, or chart, represents the concensus of information concerning ranges received from instrument manufacturers, scientists, consulting engineers and other authorities to whom photostats of this chart were submitted; and it is worthy of mention that *no two agreed*, except on some of the high-vacuum gages, the performance of which has been reported only by their inventors or authoritative users. As Dr. Sanford A. Moss* commented, "Nobody can say whether or not I am right or you are right."

Remote Indication and Recording is often desirable and apart from its convenience it allows the installation of the pressure-responsive element with a short connection to the point of measurement. It precludes, of course, the use of visible column and other "primary" instruments.

Static and Differential—Another important industrial distinction is between instruments designed for the measurement of one pressure, and those for the measurement of differential heads. It is to be noted here that the former instruments are generally known as *static* pressure gages—which is a convenient usage though it must not be understood to mean that such gages can only measure "Static" pressure in the engineering sense, and cannot measure "Total" pressure, etc. In the case of the latter instruments—the differential pressure manometers and gages—an important industrial consideration is that such instruments, while measuring a differential which may be small, must at times—and at the *same* time—withstand a high static pressure. This requirement has led to the development of float type U-gages, for example, which accurately measure a differential of 0 to 2 in. of mercury while withstanding a line pressure of 2000 lb. per sq. in. Not only is it impracticable to use glass in the construction of such instruments, but even to transmit mechanically the

*Engineer, Thomson Research Laboratory, General Electric Co.

motion of the float to a pointer or pen—so that electrical, electromagnetic, or magnetic methods are employed.

Variability—Few pressures requiring measurement in industry are so steady that variations can be ignored in the selection of instruments. Most industrial gages, as a matter of fact, have been designed with a knowledge of this, and withstand the variations usually present. But some pressures vary regularly in cycles; while others fluctuate irregularly, much or little, rapidly or slowly. For exact measurement, then, there must be provided either some *correct* method of damping, or some means of obtaining a graphic record. No two pressure measurement problems are alike, but similarities have led to the development of some well-known instruments for recognized classes of applications—and of some instruments that deserve to be better known. A well-known recording instrument is the engine indicator (that name *will* persist!) providing cards where pressure is recorded against piston position. Various new chronograph and oscillograph arrangements, on the other hand, furnish useful records where time, in small divisions, is the other coordinate axis, and they *supplement* the ordinary daily-chart recorders.

The Appearance Factor also emerges as a distinctly modern criterion in classifying industrial pressure instruments. It takes in some really practical considerations such as size, shape and mounting, which are not to be ignored when laying out a boiled panel board, for example; as well as a due regard to convenience and human efficiency—"readability," illumination, etc.

These practical considerations completely overshadow the question of whether or not an instrument "can be constructed and calibrated without comparison with another pressure measuring instrument." The tables in Chapter XI are designed accordingly to serve as practical guides.

5. Liquid Columns—A. General

The principle involved in using liquid columns is to oppose the pressure by liquid head, which varies not only with the height of the column but with two principal factors: (1) The variation of the density of the liquid with temperature. (2) The variation of gravitational force with latitude and elevation. These two corrections are necessary by reason of the fact that liquid head *units* imply standard values of the density of the liquid used, and of gravity. In addition, there are needed corrections for factors that affect the actual measurement: (1) Capillarity and (2) thermal expansion of the scale.

This section gives miscellaneous generally applicable data, and Section 6 considers the special case of the mercury barometer.

Mercury and water being the liquids on which head units are based, the following data refer principally to mercury and water columns. Differential density or two-liquid columns, employed for increasing the sensitivity of manometers, will be dealt with as such under the description of these instruments in chapter XI.

When Corrections Cancel

Assume a pair of mercurial barometers, adjacently located and alike in every particular except that the cistern of one is open to the atmospheric pressure while the cistern of the other is properly connected to a condenser or other vacuum apparatus . . . No need to add more.

This excellent method of vacuum measurement may be practically realized by installing side by side a mercurial barometer and a mercurial absolute

pressure gage. The latter will differ in appearance and in details of construction (see Chapter XI) designed for convenience in measuring pressures over a range many times longer than that of a barometer, but the general idea of avoiding time-consuming corrections can easily be carried out.

Temperature Corrections

For short columns these are negligible, except, of course, in precision manometers. Inasmuch as the graduated metal scale with which a liquid column is most frequently measured also expands and contracts with temperature changes, the correction may be for differential expansion, whence the origin of the expression "Brass Scale," the standard brass scale being correct at 62°F. The brass scale correction is included in the Weather Bureau barometer correction tables.

Water Column Corrections—A column of pure water exactly ten inches high at 62°F will be 0.0120 in. shorter at 39°F and 0.096 in. longer at 100°F. At 70°F it would only be 0.0078 in. longer and therefore the temperature correction need not be applied when the water standard is either 58°F or 62°F and the column is at ordinary "room" temperature. When reduction to the Standard Temperature, 39°F or 4°C, is desired, use Table X (based on the mass of 1 cc of water at 4°C being taken as unity and the absolute density in CGS units being obtained by multiplying the relative density by 0.999973) or Table XI which gives convenient factors.

TABLE X
EFFECT OF TEMPERATURE ON WATER COLUMNS

°F	°C	Density	Length of Column
32	0	0.99987	1.00013
39	4	1.00000	1.00000
50	10	0.99973	1.00027
59	15	0.99913	1.00087
68	20	0.99823	1.00177
77	25	0.99707	1.00294
86	30	0.99567	1.00435
95	35	0.99406	1.00598
104	40	0.99224	1.00782
113	45	0.99025	1.00985

TABLE XI—DENSITY OF WATER AND MULTIPLIERS FOR WATER COLUMNS

Temp. deg. F.	Density of water, lb. per cu. ft. d	Multipliers for reducing readings in inches of water column to: Lb. per sq. in. ($d/1728$)	In mercury at 32 deg. F. ($0.01178\ d$)
32	62.42	0.03614	0.07354
35	62.42	0.03614	0.07354
40	62.42	0.03614	0.07354
45	62.42	0.03614	0.07354
50	62.41	0.03613	0.07352
55	62.39	0.03611	0.07350
60	62.37	0.03609	0.07348
65	62.34	0.03607	0.07344
70	62.31	0.03606	0.07341
75	62.28	0.03604	0.07337
80	62.23	0.03601	0.07331
85	62.18	0.03598	0.07325
90	62.13	0.03595	0.07320
95	62.08	0.03592	0.07314
100	62.02	0.03589	0.07306

Mercury Columns—Table XII gives temperature corrections for mercury columns up to 32 in. and is taken, as are also Tables XI to XVI inclusive, from the A. S. M. E. Power Test Codes, Instruments and Apparatus, Part 2, Chapter 6. For any mercury column an easily remembered short-cut is the "Ten Thousand" formula: to reduce the column to 32°F, multiply the height of the column by the Fahrenheit temperature above 32, and divide by 10,000; then *subtract* the result from the exactly measured height.

Other Liquids—Exact work is usually done with water or mercury, but we give below the coefficients of expansion of some other possible manometric liquids, per degree Centigrade:

Liquid	Mean coef.	Liquid	Mean coef.
Acetic acid	0.00143	Glycerine	0.00053
Acetone	0.00162	Petroleum (sp.gr.0.8467)	0.00104
Alcohol (methyl)	0.00143	Turpentine	0.00105

TABLE XII—TEMPERATURE CORRECTIONS FOR MERCURY COLUMNS UP TO 32 INCHES

Temp. of column, deg. fahr.	Observed reading of column in inches of mercury								
	16	18	20	22	24	26	28	30	32
				Add					
—20	0.07	0.08	0.09	0.10	0.11	0.11	0.12	0.13	0.14
—10	0.06	0.06	0.07	0.08	0.08	0.09	0.10	0.11	0.11
0	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08
10	0.03	0.03	0.03	0.04	0.04	0.04	0.05	0.05	0.05
20	0.01	0.01	0.02	0.02	0.02	0.02	0.02	0.02	0.02
30	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
				Subtract					
35	0.01	0.01	0.01	0.01	0.01	0.01	0.02	0.02	0.02
40	0.02	0.02	0.02	0.02	0.02	0.03	0.03	0.03	0.03
45	0.02	0.03	0.03	0.03	0.04	0.04	0.04	0.04	0.05
50	0.03	0.03	0.04	0.04	0.05	0.05	0.05	0.06	0.06
55	0.04	0.04	0.05	0.05	0.06	0.06	0.07	0.07	0.08
60	0.05	0.05	0.06	0.06	0.07	0.07	0.08	0.08	0.09
65	0.05	0.06	0.07	0.07	0.08	0.09	0.09	0.10	0.10
70	0.06	0.07	0.07	0.08	0.09	0.10	0.10	0.11	0.12
75	0.07	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.13
80	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15
85	0.08	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.16
90	0.09	0.10	0.11	0.12	0.13	0.14	0.15	0.17	0.18
95	0.10	0.11	0.12	0.13	0.14	0.16	0.17	0.18	0.19
100	0.10	0.12	0.13	0.14	0.15	0.17	0.18	0.19	0.20

Gage and Absolute Pressures

For pressures below atmospheric, and for exact work when gage pressure is less than, say, 50 lb. per sq. in., absolute pressures should always be determined by reference to the barometric reading at the time of measurement and elevation of apparatus. For rough work, the average atmospheric pressure at the elevation of the apparatus may be taken from Table XIII.

TABLE XIII—AVERAGE ATMOSPHERIC PRESSURES AT VARIOUS ALTITUDES

Altitude, above sea level, feet	Average atmospheric pressure, Inches of Mercury at 32 deg. F.	Lb. per sq. in.
0	29.92	14.70
1,000	28.85	14.17
2,000	27.82	13.67
3,000	26.82	13.17
4,000	25.84	12.69
5,000	24.90	12.23
6,000	23.98	11.78
7,000	23.09	11.34
8,000	22.23	10.92
9,000	21.39	10.51
10,000	20.58	10.11
12,000	19.03	9.35
14,000	17.57	8.63
16,000	16.21	7.96
18,000	14.93	7.33
20,000	13.74	6.75

Gravity Correction

Inasmuch as the attraction between the earth and a body of a given mass decreases as the square of the distance from the center of gravity of the earth to the c. g. of the body, any system of weights, as the reader knows, must be based on an accepted standard value of the gravitational acceleration. In pressure measurement with instruments that balance pressure against gravitation, the particular location—with regard to latitude and to elevation above mean geodetic datum—may have to be allowed for. Table XIV gives the corrections in terms of heights of columns in inches, but the same proportional factors may be used for any linear units. (The value of g, 980.665 cm./sec.^{2}, is the internationally accepted standard value. The exact notation g, is sometimes given to distinguish it from g_{45} which has the value of 980.616).

TABLE XIV—CORRECTION OF MERCURY COLUMNS TO STANDARD GRAVITY

North latitude degrees	Elevation, feet: 0	0	2000	2000	4000	4000	6000	6000
	Height of column, inches of mercury: 30	28	28	26	26	24	24	22
25	—0.05	—0.05	—0.05	—0.05	—0.05	—0.05	—0.06	—0.05
30	—0.04	—0.04	—0.04	—0.04	—0.05	—0.04	—0.05	—0.04
35	—0.03	—0.03	—0.03	—0.03	—0.03	—0.03	—0.04	—0.03
40	—0.02	—0.01	—0.02	—0.02	—0.02	—0.02	—0.03	—0.02
45	—0.00	—0.00	—0.01	—0.01	—0.01	—0.01	—0.01	—0.01
50	+0.01	+0.01	+0.01	+0.01	—0.00	—0.00	—0.00	—0.00

Meniscus Correction

This should come first in practice because without it the casual "observation" is not "the reading" of the column, desired in close work. The phenomena of capillarity are familiar. Opposite effects occur when a liquid wets a solid as in the case of water and *clean* glass (Fig. 214, *a*); and when a liquid does not wet a solid as in the case of clean mercury and clean glass (*b*). The curved surfaces are known as menisci.

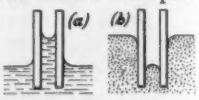


Fig. 214

A meniscus surface in a tube should always be read at its center—the bottom in the case of water and the top in the case of mercury—before applying the correction.

The rise (water) or depression (mercury) is most pronounced in the case of small-bore tubes, whence the name capillary. For water and clean glass the extra height amounts in inches to 0.046/d where d is the inside diameter in inches. Thus for a tube with an internal diameter of 0.046 in., the water would stand one inch higher than the outside surface. It is generally believed that this effect cancels out entirely in a U-gage but that is true only if the inside diameters of the two legs are alike. For example, in a U-tube with the diameter of one leg ⅛ in. plus 0.01 in. and that of the other ⅛ in. minus 0.01, it will be observed that the water stands $\frac{1}{16}$ in. higher in the smaller tube.

For mercury meniscus and capillarity corrections, see Table XV.

Capillarity rise or depression becomes negligible when the internal diameter of a tube is greater than half an inch. Thus, for a ½ in. tube, the visible meniscus height may be divided by about 11 to obtain the correction with reference to the center surface of the meniscus.

Capillary effects diminish with rise in temperature (ultimately zero because at critical state, a liquid and its vapor become identical).

TABLE XV—MERCURY-MENISCUS OR CAPILLARITY CORRECTIONS

Not to be used with barometers, where the meniscus correction is allowed for in the setting of the scale. The correction is in inches and is to be added to the reading of a mercury column comprising a single leg and a reservoir of appreciable area. The table can be used also for a mercury U-tube with legs of different diameters. The reading is to be taken at the top of the meniscus.

Internal diameter inches	Height of meniscus in inches: 0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08
	Correction in inches to be added							
0.15	0.024	0.047	0.069	0.092	0.116	...	...	...
0.20	0.011	0.022	0.033	0.045	0.059	0.078	...	...
0.25	0.006	0.012	0.019	0.028	0.037	0.047	0.059	...
0.30	0.004	0.008	0.013	0.018	0.023	0.029	0.035	0.042
0.35	...	0.005	0.008	0.012	0.015	0.018	0.022	0.026
0.40	...	0.004	0.006	0.008	0.010	0.012	0.014	0.016
0.45	...	...	0.003	0.005	0.007	0.008	0.010	0.012
0.50	...	...	0.002	0.004	0.005	0.006	0.006	0.007
0.55	...	...	0.001	0.002	0.003	0.004	0.005	0.005

Correction for Different Atmospheric Level

The correction herewith, for exact work as in important tests, is for difference between the atmospheric pressure at the level of the measured pressure vessel condenser, main, etc., and the atmospheric pressure at the level of a gage or open-column manometer influenced by atmospheric pressure. The correction is found by multiplying the value given in the table by the difference in elevation in feet, divided by 100. The correction is applied to the gage reading as follows: For a gage reading below atmosphere, and set at a low elevation; *subtract*. For a gage reading above atmosphere, set at a low elevation; *add*. For a gage reading above atmosphere, set at a high elevation; *subtract*.

TABLE XVI—CORRECTIONS FOR BAROMETERS AND PRESSURE GAGES, IN INCHES OF MERCURY FOR DECREASE OF ATMOSPHERIC PRESSURE PER 100 FT. INCREASE IN ELEVATION

Mean altitude, in feet	Mean atmospheric temperature, deg. fahr.						
	−20	0	20	40	60	80	100
0	0.13	0.12	0.12	0.11	0.11	0.10	0.10
1000	0.12	0.12	0.11	0.11	0.10	0.10	0.10
2000	0.12	0.11	0.11	0.10	0.10	0.10	0.09
3000	0.11	0.11	0.10	0.10	0.10	0.09	0.09
4000	0.11	0.10	0.10	0.10	0.09	0.08	0.08
5000	0.10	0.10	0.10	0.09	0.09	0.08	0.08
6000	0.10	0.10	0.09	0.09	0.08	0.08	0.08
7000	0.10	0.09	0.09	0.09	0.08	0.08	0.08

Coloring Water Columns

Add a few drops of one per cent alcoholic solution of fluorescein to a liter or quart of water. The dilute solution of fluorescein is bright green by reason of its fluorescence, although colorless by transmitted light. A small quantity of an aqueous (1%) solution of uranine (the sodium salt of fluorescein) may be used in place of the alcoholic solution mentioned above.

If solutions showing color by transmission are desired, dilute aqueous may be made with any of the following dyes:

Dye	*Color*	*Dye*	*Color*
Erythrosine	Pink	Napthol green	Green
Eosine	Pink (green fluorescence)	Methylene green	Bluish green
Rhodamine B	Pink (red fluorescence)	Methylene blue	Blue
Ponceau 2R	Scarlet	Methyl violet	Purple

Carbon Bisulphide may be colored with iodine.

Alcohol has to be colored when it is used against kerosene in sensitive differential-density or two-liquid U-gages. A number of anilin dyes insoluble in kerosene are on the market.

Purification of Mercury

There are four common methods in vogue for purifying dirty mercury: (1) Distillation, (2) Filtration, (3) Agitation with air, and (4) Washing with acid or alkali solution. The following directions are those advocated by The Foxboro Company:

Purification by Distillation—Mercury which is in a badly amalgamated condition must be distilled in order to produce a pure grade of mercury. It is impossible to acid wash or filter such mercury and secure a pure product. The distillation of mercury may be carried on in two ways; either under vacuum or by the ordinary straight distillation. The purity of the mercury is about the same for either method of distillation. In either case, oily matter and a few of the volatile metals distill over with the mercury vapor. The vacuum distillation outfit is somewhat complicated and requires greater care in handling than the ordinary type of distillation. It possesses the advantage that the distillation is carried on under a lower temperature and therefore does not require the amount of heat necessary to produce evaporation of mercury. For ordinary purposes, the straight distillation is preferred, as the apparatus is more sturdy and the results obtained are satisfactory.

The apparatus consists of a Nevada or open-top iron retort with a ground-in cover. This type of retort offers a distinct advantage over other types in that it holds more and there is space for expansion in the cover, preventing the possibility of fracture from expansion. The cover is held in place by a heavy yoke with a wrought-iron wedge key, which will tighten and lock the cover in place with one blow of a hammer, and unlock as readily. They are made in capacities of from 12 lbs. to 175 lbs. of mercury. The condenser consists of a 30″ length of ¼″ iron tubing surrounded by a 2″ pipe as a water jacket. The retort is fired by gas. By shielding the retort with an asbestos shield, the quantity of heat required to distill the mercury is materially reduced. The distillation is carried on at a fairly rapid rate; care

must be taken, however, to see that all of the mercury vapor is condensed, as the mercury fumes are very harmful to inhale. The mercury that is distilled should be acid washed in order to produce a clear, bright mercury, as the product of distillation carriers over with it certain impurities which acid treatment will readily remove.

Purification by Filtration—Mercury which contains impurities that are not amalgamated with the mercury can frequently be purified quite rapidly by merely filtering through a chamois skin. Acid treatment should follow the filtration in order to obtain a finished product.

Purification by Agitation with Air—Where a mercury still is not available and when the mercury is not too badly amalgamated, agitation with air may be substituted for the distillation process. In order to accomplish this, it is only necessary to place the mercury in a fairly large container and introduce compressed air at the bottom of the container so as to produce a violent agitation. This is continued for a period of 24 hours. At the end of this time the air is turned off and the scum is allowed to settle out. The mercury thus obtained is acid washed and a very bright appearing mercury is the result. The zinc, copper, and lead are completely changed to oxides by air agitation.

Purification by Nitric Acid—Make a solution of nitric acid of about 5% strength, specific gravity 1.03. Mix the mercury with about an equal volume of the acid in a glass or porcelain-lined vessel; a shallow vessel will be more effective because of the greater surface exposed to the acid. Stir or agitate the mercury and acid thoroughly in order to bring each particle of mercury in contact with the acid. Let it stand about 15 minutes and stir again thoroughly. Pour off the acid and thoroughly wash the mercury with water. Water under pressure may be bubbled through the mercury until all traces of the acid are removed. Pour mercury into a tall, slender receptacle and remove excess water with blotting or filter paper. Filter through chamois skin. The mercury should now be clean and ready to use. *Caution:* In washing the acid out of the mercury, special care should be taken that the last trace of acid is removed from the mercury.

Purification by Sulphuric Acid and Mercurous Sulphate—This method is carried out in an apparatus which consists of a separatory glass funnel of about a half gallon capacity. The funnel is suitably supported so that a glass receiving jar may be placed at its outlet to receive the pure mercury. A small quantity of pure mercury is placed in the bottom of the separatory funnel to act as a seal and then about 300 cc. of concentrated sulphuric acid and 25 grams of mercurous sulphate are poured into the funnel. The impure mercury is fed into this apparatus from a container located above the funnel. The mercury is fed so as to produce a fine spray. The impure mercury is freed from foreign metals by the action of the sulphuric acid and the mercurous sulphate and is thoroughly dried by passing through the concentrated acid so that the pure and dry mercury may be drawn off from the bottom of the separatory funnel.

In either of the acid methods of purification, the mercury will be found to be free from any signs of acid, provided the proper procedure is followed as outlined.

6. Liquid Columns—B. Mercurial Barometry

Only a brief treatment of mercurial barometry can find place in an entirely new Handbook such as this. For complete data see the publications of the U. S. Weather Bureau (especially Circular F, price 15 cents), also the Smithsonian Meteorological Tables, the Smithsonian Physical Tables, the International Critical Tables, etc. etc. But for the best engineering treatment, see Chapters 1 and 6, Part 2, Instruments and Apparatus, A. S. M. E. Power Test Codes. The following is substantially an abstract of these excellent chapters, but is not to be considered as even a summary of the official A. S. M. E. material by readers contemplating power test work; which work should only be governed by complete official copies of the applicable portions of the Codes, obtained from the A. S. M. E.

Standard Barometric Pressure

The vacuum or back pressure above atmospheric given in a contract, specification or otherwise noted as the value for which an apparatus is designed, is called the Rated Vacuum or Rated Back Pressure. This implies also a "Standard Barometric Pressure" which may or may not be given. When the Rated Vacuum, Rated Back Pressure or the "Standard Baro-

metric Pressure" is expressed in inches of mercury, such as "28 in. vacuum" or "28 in. vacuum with 29.92 in. barometer" or "28 in. with 30 in. barometer," it is to be understood that the figures are readings of the mercury colums after reduction to 32°F (Standard Temperature).

When a Rated Vacuum or Rated Back Pressure is given, it is to be understood, if not otherwise specified, that the Standard Barometric Pressure is 29.92 inches of mercury at 32°F, for locality at sea level, or a value interpolated from Table XIII for a locality with altitude above sea level.

When a test is being run, the actual barometric pressure must be found and corrected to 32°F. The difference between this value and the Standard Barometric Pressure gives a correction which must be applied to the Rated Vacuum or Rated Back Pressure. This, then, gives a value which should be approached as nearly as possible by the actual vacuum or back pressure (corrected to 32°F), which is held during a test. Any difference calls for a correction of the results of the test. In terms of absolute pressure, the given standard prescribes that the actual absolute pressure is the difference between the reading of a mercury gage corrected to 32°F. and the barometric pressure, as it would be reported by the Weather Bureau for the actual elevation. This is to be equal to the Rated Absolute Pressure, which is the difference between the Rated Vacuum or Rated Back Pressure and the Standard Barometric Pressure.

Standard Barometric Temperature

A standard barometric pressure which occasionally has been used is one corresponding to some average room temperature, such as 60 or 70°F. In such a case, the absolute pressure is determined by subtracting the reading of a mercury vacuum gage from the reading of the barometer, without correction for temperature in either case, when such temperatures are near the standard temperature. This standard requires the use of a value for the barometric pressure different from that used by the Weather Bureau, does not take account of the possibility that the barometer and mercury gage may be in different rooms, and lacks precision.

Another standard barometric pressure, which has been described in some textbooks and steam charts, is based upon the assumption that when the term "30 in. barometer" is used, the standard atmospheric pressure of 29.92 in. of mercury column at 32°F is meant. Accordingly, on this basis the given value of 30 in. is understood to be 30 in. at some particular condition of temperature, which when corrected to 32°F. will give 29.92 in. of mercury column. This temperature has been worked out and found to be about 58°F. and systems have therefore been used in which all mercury column heights have been reduced to values corresponding to a temperature of about 58°F. In this reduction of the value of 30 in. to standard conditions, the gravity correction has been omitted. For a gravity correction such as that which would correspond to 40 deg. north latitude (a representative mean for the U. S.), the temperature at which an actual 30 in. column must be in order to correspond to 29.92 in. of mercury column at standard conditions is about 53°F. The use of any such standard is objectionable for the reason that it requires reduction of the mercury column measurements to values corresponding to a temperature different from that temperature used in physical and scientific work, and also because it requires the use of a corrected barometric pressure varying from the value used by the Weather Bureau.

Fig. 215

Fig. 217

Fig. 216

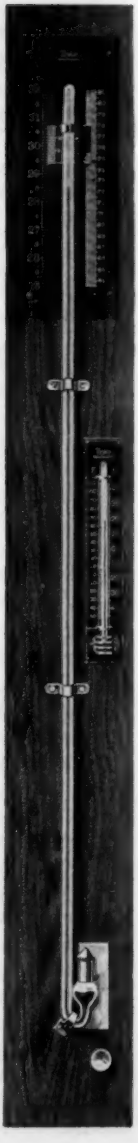


Fig. 218

TYPES OF BAROMETERS

Fig. 215 shows the "observatory" type. It consists of a glass tube somewhat more than 30 in. long, closed at one end and inverted over a small cistern. The cistern and part of the glass tube are filled with *pure* mercury. Above the mercury in the glass tube is a high vacuum giving practically "zero" absolute pressure on top of the column. The scale (usual range 26 to 31 inches) reads to 1/100 of an inch and is fastened to the metal tube surrounding the glass tube—not to the wood back. The sliding vernier facilitates closer readings. The thermometer gives the temperature of the mercury column. A mirror on the wood back prevents errors of parallax.

Fig. 216 shows the "marine" type with variable zero level allowed for in scale graduation. Fig. 218 shows a syphon type with scale graduated in tenths of an inch and vernier for hundreths. The scale is sliding, to allow for changing level of mercury in cistern.

Fig. 217 shows an aneroid barometer designed for plant service, with movement compensated for temperature.

(All cuts on this page *Taylor Instrument Companies*)

In all of the standards above mentioned, the readings of the mercury gage and of the barometric column are both to be corrected to the same temperature basis. Hence, the expression of the absolute pressure in inches of mercury, according to any of the standards indicated above, differs from the expression of any one of the other standards merely by a difference in the temperature corrections applied to the readings of usually short mercury columns. That is to say, while the different standards give appreciable differences in the corrected readings of the mercury gage and the barometer, there is very little variation in the *difference* between the two which measures a *small absolute pressure*. Hence, steam tables and steam charts using the 32°F. or the 58°F. standard for absolute pressures in inches of mercury, may be used interchangeably with negligible error, so long as small absolute pressures are adhered to, and so long as the temperature corrections, in both the barometer and the mercury gage giving the vacuum, are made according to the same standard.

A given absolute pressure expressed by a height in inches of mercury at the standard here used of 32°F. is 0.26 of 1 per cent less than the height in inches of mercury at 58.1°F.

Range and Accuracy of Barometers

Mercurial and aneroid barometers usually have a range of from 25 or 26 to 32 inches of mercury. Special barometers for use in mountainous regions begin at 15 inches or 20 inches. Mercurial barometers are usually supplied with verniers which give readings to 0.001 in. However, extraordinary precautions are required to give accuracy to this amount. A good mercurial barometer with the inner bore not less than 0.25 in., carefully maintained and carefully calibrated, will give results accurate to about 0.002 in. to 0.01 in. It is common to read and correct mercurial barometers to 0.001 in. However, for many engineering purposes, readings and corrections to 0.01 in. are amply accurate.

Installation of Barometers

The observer must verify the following matters:

(*a*) The barometer must be installed so as to be free from vibration, air currents and violent temperature changes.

(*b*) It must be in a good light, but not directly exposed to the sun, and not heated by an electric lamp in proximity.

(*c*) A mercurial barometer must be hanging freely so as to insure the vertical position of the column.

(*d*) There must be a small vent, so that atmospheric pressure reaches the interior of the cistern of a mercurial barometer.

Blowers supplying air to boilers, turbo-generators, etc. create appreciable pressure differences around a plant, and, if these are present, the barometer must be located close to the condenser or other gages with which it is concerned. The effect of the change of pressure of the air with elevation must either be eliminated, by having the barometer and gages on the same level as the apparatus in test, or else allowed for when appreciable.

Precautions in Reading Barometers

Elevation—The elevation of the barometer must be considered. There is a correction of about 0.01 in. for each ten feet variation of elevation due to a decrease of atmospheric pressure with an increase in elevation. If the necessary degree of accuracy, or the difference in elevation warrants, there

must be recorded the difference in elevation between the center line of the apparatus under test, and the barometer cistern level. There is also the correction for the elevation difference of mercury U-tubes.

In the case of a barometer being *read for calibration* by comparison with Weather Bureau readings, there must be found (to the requisite degree of accuracy) the elevation either above sea level, or with respect to the elevation of the nearest Weather Bureau station. The standard of reference to be used is that of the Weather Bureau, which is the "Mean Sea Level," as defined by the Coast and Geodetic Survey.

Reading the Mercurial Barometer—The thumbscrew at the bottom of the cistern must be adjusted so that the top of the mercury just touches the ivory point, and then the slider, carrying the vernier, must be adjusted to the extreme top of the mercury-column meniscus. Both of these adjustments are best made by placing a piece of white paper, or the like, behind the barometer, and making the adjustment so that the thread of white above the mercury first has an appreciable width and is decreased until it just disappears. The ivory point must not make a dimple in the cistern mercury. If the mercury in the cistern is bright enough, the ivory point and its image may be seen to just coincide. In making either adjustment, if the screw has been turned too far, go back enough to show a visible white space, and again start decreasing this space until it disappears. The eye of the observer, must, of course, always be on the level of the mercury being observed. The tube and cistern should be tapped lightly while making the adjustments and taking the reading. The reading of the vernier must then be found, and recorded. Care must be taken to record the correct decimal corresponding to the last vernier division. This gives the *Uncorrected Barometric Pressure.* For accurate work, reset the cistern level and take a check reading.

The temperature of the column must next be recorded.

Obtaining Barometric Pressure from a Weather Bureau Station

Weather Bureau Barometer System—There are U. S. Weather Bureau stations in all of the cities appearing on the daily weather maps. At each of these stations the barometer is read at 8 a. m. *Eastern Standard Time,* which is "75th Meridian Time." This gives a time in the various time zones as follows:

8 a.m. Eastern Standard Time	6 a.m. Mountain Standard Time
7 a.m. Central Standard Time	5 a.m. Pacific Standard Time

Note that Standard and not Daylight Saving time is used. At many of the stations, the barometer also is read regularly at 8 p. m. E.S.T.

Hence, when a plant barometer is read for calibration purposes, it should preferably be read at 8 a.m. E.S.T. as in the above table, or else at 8 p.m. E.S.T. if it is known that a nearby Weather Bureau station also reads at this time. Other times can be used in case of extreme necessity, if there are no storms, but such a comparison requires special attention from the Weather Bureau or interpolation between weather maps. In some places, the making of a calibration reading simultaneously with the Weather Bureau readings will require the same early rising that is required of the Weather Bureau observers. There is no good reason for waiving this.

Station Pressure—The reading at a Weather Bureau station, corrected for temperature, gravity, and the calibration constant of the station barometer is called the "Station Pressure" and this is the value which will ordinarily be asked of the Weather Bureau observer. For places within

about 20 miles of the Weather Bureau Station, this "Station Pressure" is to be used with only the elevation correction of the next paragraph.

In most cases there must be obtained from the Weather Bureau observer the "Station Level" or station elevation, and the atmospheric temperature. With a knowledge of the "Station Level" and the elevation of the point for which the barometric pressure is desired, corrections for differences of elevation can be made (Table XVI).

Sea-Level Pressure—In order to compare barometric readings at different places, and to make weather maps, etc. the "Station Pressure" is reduced by the Weather Bureau to "Sea-Level Pressure" (in accordance with tables similar to Table XVI).

In determining barometric pressure at a distance from a station, or at a period between the regular readings, the assistance of the Weather Bureau observer must be asked. From the sea-level pressure at several nearby stations, weather maps, barographs, and other data which are on file, information can be obtained which will make possible an estimate of the barometric pressure, at any place, either for any particular time, or as an average between two given times.

If such an interpolated result, thus obtained, indicates sea-level pressure, the pressure must be reduced to a value corresponding to the actual elevation. Corrections based upon the difference in elevation of the two stations are more accurate than those based upon values reduced to sea level.

Obtaining Barometric Pressure from Daily Weather Maps

Weather-Map System—There are filed daily at all Weather Bureau stations, and in many post offices and other public places, maps showing a set of isobars or lines of equal barometric pressure, and isotherms or lines of equal temperature. These are for 8 a. m. Eastern Standard Time.

Interpolation on Weather Maps—The location, at which a determination of barometric pressure is desired, should be indicated approximately, by a dot on the weather map, and the barometric pressure estimated by interpolation between the values on the adjacent isobars. There are isobars for each tenth of an inch, so that the interpolation will give the barometric pressure to one one-hundredth of an inch. If a determination of barometric pressure is needed for a time other than 8 a. m. E.S.T. the process described above must be carried through twice: first, with the weather map corresponding to the nearest time previous to the desired time, and second, with the map corresponding to the nearest later time. This determines the barometric pressure for the place in question at 8 a.m. E.S.T. on two successive days. The barometric pressure at the time in question is then to be found by proportional interpolation. Of course, this cannot be done accurately if there has been any violent change.

Correction for Elevation—The above process gives a value reduced to sea level, and it must be corrected to the value corresponding to the actual elevation (as indicated in Table XVI).

Barometric pressure obtained by telephone or correspondence for an exact time, and carefully corrected for difference in elevation and distance, will give results accurate to a hundredth of an inch. Uncertainties as to difference in elevation, time, or distance may make errors of a tenth of an inch or more. Barometric pressure obtained from daily weather maps, with good elevation corrections, will give results accurate to about a tenth of an inch with constant weather conditions.

Barometric Corrections and Reductions

The observed readings of the barometer should be corrected as shown by the sample data in the following paragraph. Proper discretion as to the required degree of accuracy must of course be used in reading, calibrating, and correcting the readings. It is to be noted that the Weather Bureau barometer scales have been set by comparison with an absolute standard so that *the correction for capillarity is included in the calibration* and must not be made separately. Any error in the scale setting is also included in the calibration correction.

Sample of a Mercurial-Barometer Reading, Correction, and Reduction—Plant: River Works, General Electric Co., West Lynn, Mass., 9 a.m. Eastern Daylight Saving Time, June 22, 1922.

Uncorrected barometric pressure (actual reading)	29.80 in. Hg
Barometer temperature, 75 deg. fahr. Temperature correction (Table XII)	−0.13 in. Hg
Gravity correction (Table XIV)	−0.01 in. Hg
Calibration correction (must *always* be made)	−0.01 in. Hg
Barometric pressure (at barometer elevation)	29.65 in. Hg
Level of barometer cistern *below* turbine center line, 16 ft. Elevation correction (Table XVI)	−0.02 in. Hg
Barometric pressure at elevation of turbine center line	29.63 in. Hg

Reduced reading 29.63 × 0.4912 = 14.55 lb. per sq. in. = absolute barometric pressure at elevation of turbine center line.

Calibration of Barometers

Barometers are to be calibrated by comparison with Weather Bureau readings which have been found in either of the two ways given under "obtaining Bar. Pr." etc. The accuracy of the calibration as made must be greater than is required for the readings. It is usually desirable to make several comparisons on successive days, and use the mean calibration correction. The barometer usually should not be moved or disturbed during use or calibration; so that the readings for calibration purposes should be taken without moving the barometer from the position where the test readings are taken. However, if there are blowers creating a pressure difference, and if these cannot be shut down for the calibration reading, the barometer may be carefully moved to a proper nearby point for the calibration reading.

A regularly installed mercurial barometer should be calibrated at occasional intervals. A calibration of such a barometer, or of a special barometer, should be made during the course of any set of tests.

The difference between the reading of a barometer (corrected for temperature and gravity) at a plant where tests are being made, and the reading for the same location as obtained from Weather Bureau information (with the proper corrections for time, distance, and elevation), gives a constant *Calibration Correction* which must be made to each reading of the barometer. The error is usually due to one or more of three causes: an error in the scale, an error in the scale zero, and the presence of air in the glass tube above the mercury. Air or an error in the scale will give a variable error, while an error in the scale zero will give a constant error. However, the reading of the barometer usually varies so little during a period of test, that the error may, for engineering purposes, be taken as a constant error. The calibration correction also includes minor errors of capillarity, alignment of vernier zero, etc. In the case of a good barometer carefully maintained in a plant, the error should not be more than a few hundredths of an inch.

If a barometer is off more than 0.3 in., or if there is any other obvious difficulty, it should be sent to an instrument shop for correction. (See

Circular F of the Weather Bureau for "Transportation Instructions.")

Example of Calibration—Made from 8.00 a.m. reading of a Weather Map. Plant: River Works, General Electric Co., West Lynn, Mass., 9 a.m. Eastern Daylight Saving Time, June 22, 1922.

DATA	
Uncorrected barometric pressure	29.800 in. Hg
Check reading	29.801 in. Hg
Temperature	75 deg. fahr
Height of cistern above floor	3 ft.
Floor elevation above mean sea level as given by plant engineer	16.82 ft.
Latitude	42.8 deg. N.
CALIBRATION	
Mean uncorrected reading	29.80 in. Hg
Temperature correction	−0.13 in. Hg
Elevation correction	0.02 in. Hg
Gravity correction	−0.01 in. Hg
Corrected reading, reduced to sea level	29.68 in. Hg
Weather map reading, reported by Boston station of U. S. Weather Bureau 8.00 a.m. Eastern Standard Time, June 22, 1922, reduced to sea level	29.67 in. Hg
Calibration correction	−0.01 in. Hg

"No plant barometer can be trusted without calibration."—A.S.M.E.Code.

7. Dynamic Behavior of Pressure Instruments

Mention was made in Section 1 of a noted scientist's unwittingly comical remark implying that the inertia of a mercury column is greater than that of a water column (supporting the same pressure and hence of equal weight). The question involved, as regards the behavior of the indicating element of an instrument (in this case the top of a liquid column) is one of considerable importance as affecting the intelligent selection of the best instrument for a given purpose. It applies not only to pressure measurement but to all instruments in general, including balances, electrical instruments, etc.

(Whenever an engineer *deliberately* selects a water column instead of a mercury column in order to waste less time waiting for it to come to rest, he takes into consideration one aspect of what is known as the dynamic behavior of instruments. When the user of an old, "sticky" pressure gage, pressure-spring thermometer or millivoltmeter taps it once and takes one reading, he does *not* observe these principles. If he takes several readings in succession, tapping it before each, he displays *awareness* of these things. If he is the sort of engineer whom others look up to when instruments are mentioned, he then usually possesses *understanding* of dynamic behavior.)

It must be evident from the definitions of sluggishness and variance that the absolute values of these factors are somewhat hard to determine, and that the effect of these undesirable properties upon a given reading depends in part at least upon whether that reading was gradually approached by a slow change in the actuating *force* or whether it was reached by a sudden change. In the latter case, inertia effects in the mechanism enter the problem, and it becomes necessary to examine the instruments briefly with regard to their behavior under *static* and *dynamic* conditions.

We may first of all sum up the whole discussion by declaring that the *difference* between the subject of damping and the subject of dynamic behavior lies in the answer to the question, "*Where* does the indicating element come to rest?"

Schlink in the U. S. and Gramberg in Germany have treated this subject at length. From the former we borrow two records, Figs. 219 and 220, a comparison of which is the best possible graphic summation. From the latter's *Technische Messungen*, Diederichs and Andrae* have adapted an excellent discussion—to which the following is gratefully credited.

*Loc. cit.

Static Behavior

Consider first an ideal instrument, that is, one without sluggishness or variance. Let the force produced upon the mechanism by the pressure P_x, which is to be measured, be called the driving force P_d, and designate by P_c the resisting or control force produced thereby in the mechanism of the instrument, by means of liquid column, springs, weights, etc. Under these conditions, any driving force P_d will cause a motion of the indicating element until the control force $P_c = P_d$, when the mechanism will again be in balance. Without variance, the indicating element will always show

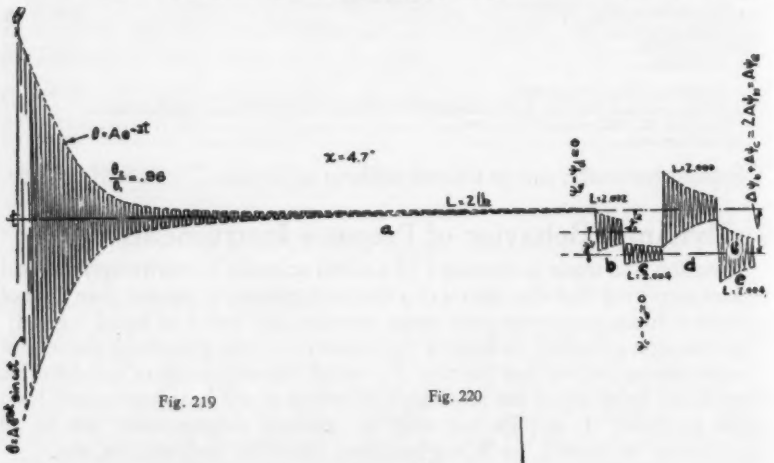


Fig. 219

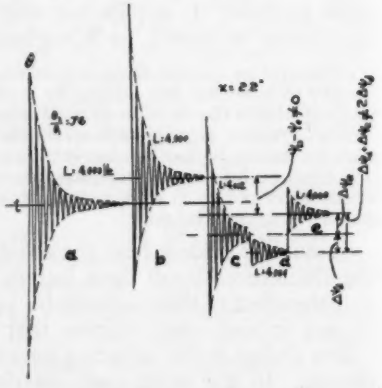


Fig. 220

Two of the photograpically recorded oscillograms published by Schlink more than 10 years ago, which led to better understanding of variance. The behaviors of two balances were compared. The horizontal axis is that of time, while the vertical axis is that of angular displacements from the initial plane of balance. The values of the load corresponding to each oscillogram are lettered in. In Fig. 219, *a* is the oscillation for the scale with a load of 2.000 lb., the distance *x* from the vertical plane through the load knife-edge being 4.7 ins. In *b*, an increment of 0.112 lb. has been added, and in *c* an additional 0.002 lb. At *d*, both increments have been removed together, and at *e*, both have been re-added together. Note the accuracy with which the axes of *a* and *d*, and *c* and *e*, coincide. In Fig. 220, curves *a* and *b* are identical conditions, the scale simply being allowed to come to rest at the end of *a* and re-started for *b*. Note the variability of rest-point here exhibited, and expressed analytically in the equations accompanying the figures.

the same reading of P_c for unchanging value of P_d. As long as balance does not exist, there will be a displacement or restoring force $P_r = P_d - P_c$, which becomes equal to zero in an ideal instrument when $P_d = P_c$. The ratio of the value of this restoring or displacement force P_r, for a small displacement from a balanced position, to the force of friction F determines the sluggishness and the variance of an actual instrument. An analysis will show that the value of this force P_r is a function of the manner in which the forces P_d and P_c vary with the displacement S, of the indicating element above a certain datum. It follows that P_r is a function of the design of the instrument, and is not under the control of the user, but an understanding of the interrelation of P_d, P_c, P_r and F may guide an engineer in selecting the best instrument for his purpose.

In a liquid manometer the driving force P_d, produced by the pressure, is independent of the movement of the column, as long as the pressure is constant. Hence in Fig. 221, P_d is parallel to the axis of S. The control force P_c, on the other hand, is a direct function of S, and follows the line laid down in Fig. 221. In indicators and spring loaded pressure gages the conditions are the same. Here any value of P_d, as P_d', Fig. 221, cuts the line P_c in a definite point A', to which belongs a definite displacement S'. For any other value of P_d, as P_d'', we have another definite displacement S''. In other types of instruments we may have different conditions. Thus

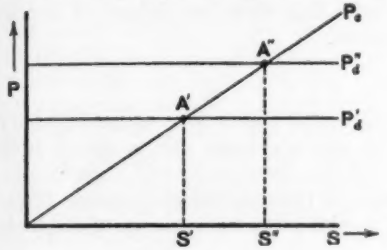


Fig. 221

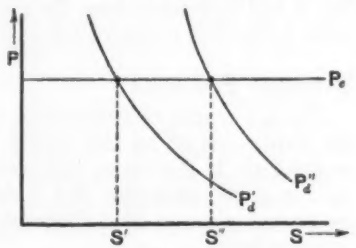


Fig. 222

in flow meter U-gages employing loaded floats, the control force P_c is constant and independent of the movement of the float, that is, of S, Fig. 222, whereas the values of P_d may vary as indicated. Again we have, for definite values of the pressure P_d to be measured, definite points of intersection and definite float positions.

In the general case then, we have the conditions as outlined in Fig. 223. A given value of P'_d determines the value S' by the intersection of P'_d with P_c. If now the indicating element is deflected out of its equilibrium position an amount dS', there will be produced a restoring force P_r measured by the algebraic sum of the changes in P'_d and P_c. Accordingly, expressed in the unit of length of scale, the restoring force

$$P_r = \frac{dP_c}{dS'} - \frac{dP'_d}{dS'} \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

For every value of the pressure P_x to be measured, there is a definite curve P_d', P_d'', etc. If the laws of variation for a given instrument are as outlined in Fig. 223, the value of P_r decreases with decreasing values of S. For $S=0$, the curves P_c and P_d'''' are tangent, hence at A_o, $P_r=0$, that is, there is no restoring force. At this point, therefore, the indicating element, lacking any directing force, may take any position, making the absolute error of reading very great. This is a condition that must be avoided in design. The presence of friction adds to the uncertainty of the indication, for if in Fig. 223 we draw two lines parallel to the curve for P_c, at distances $+F$ and $-F$, F representing the effect of friction, it will be seen that there is to begin with, for any point such as A'' with true position S'', uncertainty in the position of the indicating element in the range S_1''-S_2''. The extent of this uncertainty is less the more nearly the P_c and P_d curves cut each other at right angles, for this condition controls the magnitude of the restoring force P_r, necessary to overcome friction. This favorable condition can evidently be reached either by increasing P_c or decreasing P_d with increasing S, or by both means combined.

For any given instrument the values of P_d and P_c as functions of S, and hence the variation of P_r with S, may either be computed or may be found by

calibration. Thus in a steam-meter of the loaded float type, P_e is constant for any value of S. By disconnecting the float and holding it stationary at a given position corresponding to a displacement S', the forces P_d acting on it for a series of values of the object of measurement (pounds of steam per hour, for example) may be found. In this way, using various float positions and repeating the determination of P_d for the same series of values of X, a series of curves P_d', P_d'', etc., may be determined. We then have the means of computing P_r as a function of S. It is not very often that so critical an examination of an indicating or recording instrument is called for. But it will be evident from the discussion that these are matters of importance in the first design of the instrument.

Dynamic Behavior

This is a matter of importance, since inertia effects may seriously falsify the indications of an instrument. In practice these effects occur most prominently in the *engine indicator*, and this instrument will therefore be used as a type example. But it should be remembered that *inertia effects are present whenever there are moving masses under the influence of suddenly changing forces.*

Every position of rest of the indicating element, that is, the pencil in an indicator, or the hand in a gage, voltmeter, etc., is the result of a momentary balance between the driving and the control forces. In Fig. 224, assume that such a condition held during the *time* interval AB. Now let the value of the driving force P_d change suddenly from AB to CD. This involves a disturbance of the balance between P_d and P_e, and therefore a movement of

Fig. 223

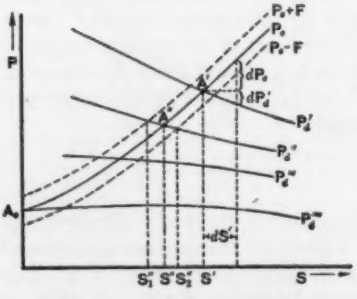
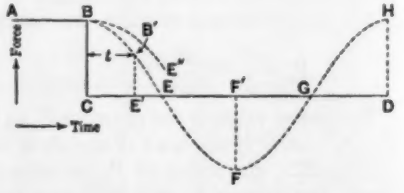


Fig. 224



the indicating element. But since the indicating mechanism always possesses weight, to cause any movement requires the application of an accelerating force. This accelerating or displacement force P_r is supplied by the momentary difference in P_d and P_e, produced by the fact that the indicating element can not follow the instantaneous, or at least sudden, change in P_d. Thus, while P_d follows the line $ABCD$, P_e follows the line BE. The ordinates between CE and BE are measures of the displacement force P_r acting on the mechanism. At the time t, for instance, the force is proportional to $B'E'$. The area under BCE, equal to $\int P_r dt$, is a measure of the kinetic energy possessed by the mechanism in motion at the point E, provided none of the energy is lost in friction. On account of this kinetic energy, the indicating element now passes *beyond* the true value E of the driving force P_d and a displacement force $-P_r$, opposite in sense to P_r, is now called into play, which brings the mechanism at rest in point F, such that the area BCE = area EFF', assuming, of course, no friction losses. At F, force $-P_r$ is a

maximum and the play of the mechanism is now repeated along *FGH* in the opposite sense, until at *H* the condition existing at *B* is re-established. Thus the mechanism is set into vibrations, which under the assumption of no friction losses, or other damping, would keep on indefinitely.

Assume now two engine indicators or other instruments, with equal strength of springs, so that P_c is the same for both. It is then evident that the instrument with the greater mass of moving parts will lag behind the greater amount, since it requires a greater value of $P_r = P_d - P_c$ to accelerate the moving mass. Or, if we have two instruments with moving parts of the same weight, it is again evident that the instrument having the weaker spring, that is, the one furnishing the smaller restoring force P_r in relation to S, will lag behind the other. In either case, whereas the pencil in the one instrument may follow the curve *BE*, Fig. 224, the other may be forced to follow the path *BE''*. The general conclusion is that the greater the value of P_r with relation to inertia of moving parts, the greater will be the frequency of the vibration set up, and the smaller will be the lag of the pencil behind the position it should have. These two factors, then, the value of the restoring force for a given difference between P_d and P_c and the weight of the moving parts, determine the natural time of vibration and, conversely, the natural frequency of vibration of the moving parts of the instrument. If *M* is the mass of the moving parts, reduced to equivalent mass at a given point, and C the force which, if applied at the same point as that at which the masses are conceived as concentrated, will move this point one unit of length, we have from the laws of physics that the time of natural vibration:

$$t_n = 2\pi\sqrt{\frac{M}{C}}. \quad . \quad . \quad . \quad . \quad (2)$$

The reciprocal $1/t_n$ is the frequency of vibration. From (2) it is evident that t_n increases with *M* and decreases as C increases.

Up to now, resistances to the motion, other than that due to control elements, have not been considered. These consist of friction in bearings, of air resistance and other resistances artificially introduced. Resistances of any kind cause a gradual dying out of the vibration. An instrument having such artificial resistance is said to be *damped*. Damping, unless excessive, does not materially affect the frequency of the vibration, but it does decrease the successive amplitudes. We distinguish between damping by solid friction, called *mechanical damping*, and by means of other resistances, called *molecular damping*. It makes a considerable difference in the dynamic behavior of an instrument whether the former or the latter type of damping predominates in a given case. Mechanical damping is independent of the velocity of the rubbing parts, whereas the degree of molecular damping converges to zero with the velocity. The latter therefore is most active at high velocities, the effect being minor at low velocities, whereas mechanical damping affects the readings throughout, the friction of rest being even greater than that of motion. Usually both kinds of damping are present, in which case the instrument is said to have *double damping*. It is possible to introduce molecular damping by means such as vanes, magnetic dampers, etc., which are "external," that is to say, outside of the instrument case; but such methods of damping are essentially *internal* as distinguished from damping or "deadening" of the variations in the pressure or other force acting on an instrument. It is the latter method of damping or deadening which is *external*.

In Fig. 225, Curve 1–1 shows the vibration for the undamped instrument, produced by the pressure drop *BC*. Molecular damping alone may produce the curve 2–2, in which the successive vibrations have steadily decreasing amplitudes, but which in theory never die out. An instrument having both

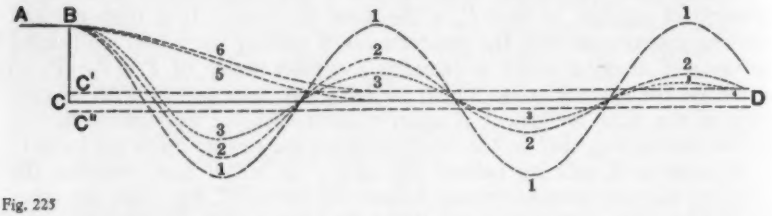


Fig. 225

molecular and mechanical damping may give the curve 3–3, which at 4 dies out. In this case the two parallels C' and C'' represent the frictional resistances $+F$ and $-F$. The vibrations die out, but the indicating element will show variance between the limits of C' and C''. It is possible, by increasing F, to kill the vibrations even more quickly, but at the expense of accuracy due to increased variance. Friction is therefore harmful, and it would be better to reduce the vibrations more quickly to a permissible degree by the use of molecular damping. It is also possible by the use of excessive damping to use up all of the available kinetic energy represented by the area *BCE*, Fig. 224, in the first half period of vibration. The instrument then follows the curve 5, Fig. 225, if the damping is molecular, but curve 6 is followed if the damping is double, as it usually is. The instrument is then said to be *aperiodic* or *deadbeat*. Although this type of instrument has some desirable qualities, it has the disadvantage that it is difficult to get an idea of the variance. On the whole, an instrument in which the friction is reduced to the minimum, so that variance can be determined and is of tolerable amount, and which is molecularly damped, so as to produce the curve 3–3, is to be preferred.

Finally, the picture here drawn is modified by the fact that, except in a measure in the case of electrical forces acting on instruments, the transition of the value of an impressed force P_d from a value *AB* to a value *CD* is not instantaneous, as assumed in Figs. 224 and 225. Such a transition requires a time interval, and takes place according to some law *BE*, Fig. 226. The line approaches *CD* asymptotically, and the change itself may be subject to periodic or aperiodic damping. The vibrations of the indicating mechanism are now superposed upon the curve *BE*, line 1–1 showing undamped vibrations, line 2–2 doubly damped vibrations, and line 3–3 the action of an aperiodic instrument, friction being neglected. The amplitudes will be smaller, and in the limit, of course, we approach static behavior. A critical examination of an instrument, with the behavior indicated in Fig. 226, will bring out that there is no advantage in using any degree of damping which kills out the vibrations in a time interval which is less than that required for the indicating element to approach somewhere near the new value of the indication, that is, before, say, the value *E* is reached on the line *BE*, Fig. 226, because the instrument can not be read before that time anyway. Another factor opposing excessive damping is the fact that, while in Figs. 224 and 225, the amplitudes of vibration were equal to the value of the change *BC* in the impressed force, unless damped out, in Fig. 226 the amplitudes are much smaller than the change *BC*, even in an

instrument without damping. And the amplitude of these vibrations will be smaller, the higher the frequency. It is possible then in these cases to have a satisfactory instrument, even without much damping, provided the frequency of vibration is made high by reduction of inertia effects or by

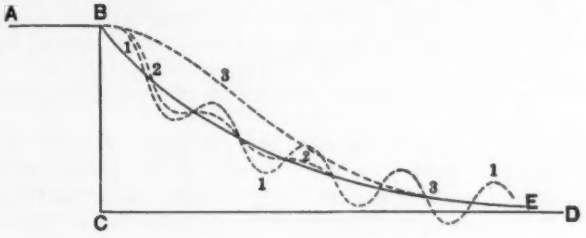


Fig. 226

increase of restoring force, or both. This is emphatically the path to be pursued when dealing with such instruments as the piston indicator.

This entire discussion has been summarized by Diederichs and Andrae in the following rules for the construction of indicating or recording instruments:

(*a*) The natural period of vibration of the moving mechanism is to be made as high as possible, through reduction of weight of moving parts and increase of restoring force.

(*b*) The solid friction resistance must be reduced to a minimum, and

(*c*) Molecular damping may be introduced to near the condition of aperiodicity.

Weight reduction may be realized by the use of specifically stronger materials, like high carbon steels, or specifically lighter materials like aluminum. The restoring forces may be increased in a variety of ways. In indicators, through the use of larger pistons with correspondingly stiffer springs, in loaded float meters by increasing the weight, etc., in electrical instruments by increasing the number of windings in a coil, etc. Generally these means also result in some increase of weight, so that a part of the effect is lost. Friction can be reduced through the application of *Kinematic Design* principles as advocated by Pollard. Molecular damping may be introduced by means of dash-pots or fan brakes, or by means of metallic drag plates in conjunction with permanent magnets. It should not be forgotten,that in some cases the method of use of an instrument has an influence upon the conditions of vibration and damping. Thus, in an indicator used on a hydraulic cylinder, the fluctuations of pressure are accompanied by a movement of the liquid in and out of the indicator cylinder and connect.ons. This, in effect, serves to increase the weight of the moving masses, and thus affects the period of vibration. Different lengths or diameters of connections will in this case have very different effects upon the instrument, independent of what means for control have been adopted in the instrument itself. See Sections 8 and 10.

It is a good rule to work only with good instruments. The faults of a bad instrument are difficult to minimize by means of calibration, and excessive solid friction should never be tolerated on account of the great degree of variance it introduces, since one is never certain whether a given reading has been reached by motion of the indicating element from below or above.

8. Variable and Fluctuating Pressures

We are only concerned here with rapid variations affecting measurement.

As mentioned in Section 4, no two problems are alike, but those involved in engine tests have led, by reason of their universality and importance, to the development of indicators which *record* the pressure over a complete cycle.

Leaving engine cylinder pressures out of the picture, there remain vast fields—at first sight riotous jungles whose hopeless confusion discourages exploration. Only at first sight: By noting similarities we may lay down

some broad but suggestive classifications of these innumerable measurement problems:

The basis of the first classification is, how often is accurate knowledge desired? The answers determine an arrangement into three divisions: (1) Cases where accurate measurement is *never* required, so that "pinching the gage cock" or other such rough means will always do; (2) Cases calling for *occasionally* disconnecting the gage and connecting instead an engine indicator of the proper range, its drum being manually rotated for each card; (3) Cases calling for the *permanent* installation of a suitable recorder with a rapidly-moving chart.

A second classification has in view the amplitude of rapid variations: Variations that are "small" (on the yardstick of the desired accuracy of measurement) need not be considered here, for they are ignored in practice. Larger variations, such as are considered here, can be graded by size along two different lines: One way would be to take the maximum pressure as a unit and express maximum variations as percentages; another way would be to take the required accuracy of measurement as the unit and the maximum (or other) variations as *multiples*. (Fractional variations would not matter.)

A third classification would be along the lines of wave form studies . . . when there are wave forms to study: (1) All harmonic regular pulsations, representable by curves symmetrical about the axis of the true mean pressure, would go into the highly-preferred first class, because any proper method of damping will make the instrument read the true mean; while (2) all other variations—including most pulsations—would constitute the second class.

But here we come on a subordinate yet extremely important division: Even among variations which do not produce equal areas above and below the center of a graph: (2A) some are in the nature of cyclic or regularly recurrent variations, the form of which is irregular but *not* variable, while (2B) others are "irregular in their irregularity." Examples of the former are the pressures near many reciprocating pumps and compressors; examples of the latter are the pressures downstream from faulty regulators.

The former pressures, class 2A, are usually believed to be extremely difficult of measurement because external damping seldom gives the true mean and the hands of undamped gages oscillate so much that reading amounts to guessing. The author believes that in the majority of such cases it is possible to obtain a calibration correction for the damped reading, and recommends the following procedure: Install a branch instrument line (see Section 10) *ahead* of the capacity tank or other means of external damping but from the *same* pressure opening (see Section 9) to which the gage is connected. This branch is to serve a suitable "inertialess" sensitive recorder—high-grade engine indicator, electrical-resistance pressure recorder, etc.—which if not available in your plant may be rented. Adjust the damping until the gage can be read (but don't pinch off until the pointer stands still). Take a series of cards, chart records or oscillograms—depending on the instrument—with equal time divisions. Mark on each the simultaneous gage reading. Compute the true mean pressure on each graph. Compare each with the corresponding gage reading: if the difference is *constant*, it can be applied as a constant correction for the range of working pressures. If the difference is not constant, study of a sufficiently extensive series of graphs may show that it is possible to obtain a correction as a function of the gage reading—which is nearly as satisfactory.

The classification of *fluids* whose pressure is to be measured suggests immediately (1) in gases the effects of elasticity, the transmission of variations at gas velocity plus the speed of sound, velocity variations accompanying pressure variations, etc.; and (2) in liquids various inertial effects in the lines to the instruments (see Section 10). All proper subjects of thorough investigations, which even now are being carried on by engineering bodies here and abroad, and from which industry will greatly benefit.

A fifth method of classification is into (1) those cases where the true (not the arithmetic) mean pressure is desired, and (2) those calling for knowledge of maximum or minimum or both. For mean pressure no general rule can be given to instrument *users* except to place the facts of each case before an instrument firm that has a good engineering department (but see "Damping" below). For knowledge of maxima and minima, records must be obtained.

A sixth division is into (1) those variations consisting of sudden changes at irregular intervals during which the pressure is steady, and (2) the more usual "sawtooth" or "scallop" variations. The former cause the indicating elements of instruments to overshoot and frequently to wabble before coming to rest (see Section 7). The latter are intensified on gages by correspondence or harmonics with the natural period of the mechanism, so that if they are of variable frequency (as is often the case) the gage hand will at times stand still and at other times vibrate over a wide arc. Every reader has noticed this effect even with damping.

Sudden changes of liquid pressure, serious enough to injure instruments other than crusher gages where permanently installed instruments are preferable, are not "variations" and are beyond the province of a chapter on pressure measurement. They seem to call for removal of the causes.

Damping

After the discussion of damping of instrument mechanisms in Section 7, and after the above comments on variations, the reader is no doubt prepared for the following:

1. Apart from such distinctions as inertial, molecular and other methods, damping—from the user's point of view—is either *internal damping*, a property of the instrument; or *external damping*, something he must attend to himself. Modern mechanical and electrical instruments for pressure measurement are designed with due consideration to internal damping. That is to say some are carefully designed for high sensitivity with deliberate minimization of damping; others are carefully designed for accuracy of measurement together with such inertial damping as heavy pointers or viscous retardation methods, etc.; and others still strive to combine two or more desirable properties. Some of these instruments, as well as self-damping *liquid* manometers, are described in Chapter XI. For the majority of pressure measurement applications where variations are not both rapid and "large" (see above) there are available suitable instruments. But what of the other applications—those where variations seem to call only for external damping?

2. Except in rare cases, external damping causes errors that should not be tolerated. We may continue parenthetically:

[3. The subject of pressure variations should therefore be put on an engineering basis, with recognized designations for the various classes of "pulsations," "fluctuations," "forms," etc. and with recognized "ranges," the latter implying recognized conventional scales of amplitude.

4. Pressure instruments should then be developed more generally (a good start has been made) with regard to the measurement of each recognized class of variable-pressure measurement problem.

5. The user should be relieved of the necessity of either conducting a scientific investigation before installing an instrument for measuring variable pressure or purchasing an expensive graphic apparatus to obtain accurate measurements when an inexpensive indicating gage (provided with the exact method of internal damping required) would serve his purpose.

6. The user of industrial pressure instruments would then be responsible only for eliminating connection errors (Sections 9 and 10) and would consequently pay closer attention to pressure openings and to instrument lines, knowing that the instrument maker has provided him with trustworthy means of obtaining correct visual indications as well as correct records.

In other words, the pressure instrument makers, with the help of the mechanical engineering profession, should do what the electrical instrument makers, with the aid of electrical research, have done.]

Internal Damping

The aspects of internal damping relating to design and construction have been discussed theoretically in Section 7. Their actual applications by manufacturers, in the industrial pressure instruments on the market, will be touched upon in Chapter XI. In addition to these matters which influence the *selection* of pressure instruments, there is also the practical question of what can be done in the plant to alter the dynamic behavior of an instrument which is already installed for the measurement of a variable pressure.

If the instrument is mechanical, the average user should not attempt to modify its internal damping.

If the instrument is a U-tube, damping may be introduced in the U by throttling, as by nearly closing off one of the valves embodied in some of the industrial U-gages. If the manometer happens to be a plain glass U-tube with a glass bend, obstructing the U may be resorted to. This may be done with a wad of clean asbestos cloth, glass wool or other material, chemically inert to the liquid, which will not be likely to plug up the bore. Such a damping method, though a makeshift, is preferable to external damping methods which make it uncertain that the pressure at the gage is the measured pressure.

With such a liquid manometer measuring a *regularly* fluctuating pressure, and consequently resonating objectionably, the user may try a simple application of the principles of dynamic behavior—and without damping, either: Merely increase or diminish the total liquid length. Adding or spilling a small amount of liquid will change the natural period of the column. (Formulas are given in Chapter XI.) In some cases, in order to get well away from resonance frequencies, it may be necessary to raise or lower the zero level so much that the scale will have to be shifted beyond the length of the adjusting slots, and the range of the instrument will be cut down.

Internal damping by throttling, and the change of liquid length suggested above, may both be used in combination—and should be before resorting to external damping.

Methods of External Damping

Two methods in vogue are as follows:

(1) *Throttling*—Whatever means is employed—orifice, pinch valve, the gage cock itself, etc.—should be as close as possible to the instrument.

(2) *Capacity*—Air chambers, etc., providing a volume many times greater than that of the gage line itself. Precautions should be taken as described in Section 10.

These two methods are sometimes combined.

9. Eliminating Connection Errors—A. Pressure Openings, etc.

With regard to "taking off" the pressure of a body of fluid at rest, the principal items to observe are, that the opening be sufficiently large (a minute opening would cause indications to lag whenever fluctuations occur), and that differences of elevation be considered.

But when a body of fluid is in motion, the location and arrangement of the pressure opening must be carefully studied because they influence the measurement of "the" pressure. In fact, the disposition and character of the pressure opening then determine whether the instrument will respond to Static Pressure, to Total Pressure, to Static Pressure minus a large proportion of velocity head . . . or to an unknown random mixed magnitude not worth the trouble of measuring. Regardless of the nature of a fluid, flow is associated with kinetic energy, diminished speed with increased pressure, and change of direction with pressure effects in certain directions. The discussion in this section, then, deals only with the location, size and shape of pressure openings and devices in pipes, ducts and other *conduits* in which fluids are *in motion*.

Notes—(1) Data pertaining exclusively to the measurement of flow, not primarily to pressure measurement, are left for Chapter XV. (2) The precautions with regard to the connection *between* the pressure opening and the instrument are essentially the same whether it is desired to measure the pressure of a fluid at rest or of a fluid in motion, and are dealt with in Section 10. While the present section deals with the "take-off" or "opening," it must be admitted at the outset that there is no satisfactory single name for the subject, which is one that the engineering profession has only recently segregated for special studies. The "object of measurement" involved must necessarily be a particular kind of pressure: static, total, etc. The "things" involved are not merely "holes" but include devices used in connection with the measurement of the pressure "at" the conduit wall or "in" a stream. For static pressure there have been studied and specified Static Holes *and* Static Tubes; for impact pressure, there are only Impact Tubes, ending in openings (*not* known as "pressure holes") the plane of which is normal to the flow. For the sale of convenience and at the sacrifice of accuracy, the author is using the inclusive expression "pressure openings." (3) The directions herein given, while obtained in large part from sources which the author considers to be the most authoritative, must not be presumed to express the conclusions of any society, or to be in any respect "official."

Location of Openings

Irregularities—A pressure opening in a conduit where there is flow must be located with care in order to avoid errors due to impact and eddies. This is especially important when it is desired to measure Static Pressure. The character of the conduit in the neighborhood of a pressure opening should be such as to make it certain that the flow is parallel to the wall. There should be no rivet heads, jogs, or other source of "permanent" eddies in the wall close to a pressure *hole* in a conduit wall. A length of straight pipe at least equal to 5 diameters should be provided between a symmetrical irregularity such as a reducer or a sudden change in pipe size, and a pressure opening. A length of straight pipe at least equal to 10 diameters should be provided between an unsymmetrical irregularity such as an ell, globe valve, etc., and a pressure opening. A length of straight pipe at least equal to 2 diameters should be provided between a pressure opening and an irregularity of any kind.

Deviated Flow—It is best *not* to locate a pressure opening *at* a bend when the usual measurements of static, impact or total pressure are required. A directional force is exerted, which = mass of fluid deviated × change of

velocity in that direction and increases as the square of the velocity. Therefore, even for a slight and even bend, the "centrifugal" force per area is always comparable, in order of magnitude, to the value of the true impact pressure of the moving fluid. For rough measurements at slight bends and low velocity, the average of the readings of several instruments connected to several pressure openings (sometimes of only two—one on the inside of the bend and one on the outside) is found satisfactory. Such readings are worthless for exact work. The measurement of the "directional" pressure itself is beyond the province of this discussion. Formulas for water are given on page 289 of the Marks Mechanical Engineering manual and in works on hydraulics.

Corrections for "Different Locations"

In some cases it is impracticable to locate a pressure opening at the desired point. Examples are the necessity of providing lengths of straight pipe; accessibility; avoiding a point where pulsations are objectionable, etc.

Difference of Level causes variation in Static and Total Pressure. Static pressure is the same at all points on a horizontal surface in the midst of the fluid and at the boundary walls, in the case of a fluid at rest or flowing with parallel flow. The static and total pressure at different horizontal surfaces in such cases differs by the weight of a column of fluid having unit area and a height equal to the head or vertical distance between the two surfaces. If h_1 and h_2 are the respective vertical distances above any datum plane, in feet, and ρ is the density of the fluid in lb. per cu. ft., the difference of pressure in lb. per sq. in. $= \rho\ (h_2 - h_1)/144$.

For the case of *gases* at rest or practically at rest in boilers, receivers or similar vessels, or flowing in pipes of constant area, the difference in pressure at different levels is slight and is usually negligible. Hence, the pressure is assumed to be the same at all points and all levels for *gases* in such vessels or pipes of constant area. There are, however, evident cases when the weight of the gas must be taken into account by means of the equation given in the preceding paragraph.

Change in Area—Static Pressure (but not Total Pressure) changes with area when fluid flows in a closed pipe with walls so shaped as to give parallel flow at various points, but with different pipe areas at these various points. The following correction can only be used for the case of flow from a given area to a *smaller* one with gradual change. Unknown additional friction loss occurs with change from a given area to a larger one.

Let V_1 and V_2 be the respective velocities in ft. per sec. and let ρ be the mean density in lb. per cu. ft. The correction is not permissible if the respective densities, ρ_1 and ρ_2 differ from ρ by more than 2 per cent. Then the difference in static pressure in lb. per sq. in., is

$$\frac{\rho}{2g \times 144}(V_2^2 - V_1^2) \quad \text{or} \quad \frac{\rho}{9265}(V_2^2 - V_1^2)$$

If A_1 and A_2 are the respective areas in sq. ft. and $\mathcal{Q}$ is the quantity flowing in cu. ft. per sec. the values of V may be computed from the formula

$$\mathcal{Q}/A_1 = V_1, \quad Q/A_2 = V_2$$

The lower static pressure corresponds to the higher velocity.

Pressure Loss Due to Pipe Friction—The decrease of Static or Total Pressure along a straight conduit, due to friction, is given by the following formulas, so that pressure taken at a given place as a matter of convenience may be corrected to the value existing at another place where it is desired. It is to be understood that the two places shall be so near that the friction correction will always be of small magnitude, and that the conduit is straight. The friction depends on the conduit velocity. This may be computed directly from the quantity flowing, or it may be given by an observed value of the Impact Pressure. Notation:

V = velocity ft. per sec.
d = density of fluid which is flowing, lb. per cu. ft.
D = diameter of a round pipe, in feet.
a and b = height and width of a rectangular conduit, in feet.
L = length of conduit in which the friction occurs, in feet.
p_i = impact pressure or velocity head, inches of water, observed as the differential pressure between an Impact Tube and a Static Hole in the conduit wall.
A = area of conduit, square feet.
L_e = perimeter of conduit.

The general formula for friction loss, measured as "head," or height in feet of a column of fluid, is $0.0001\ LV^2\ L_e/A$.

This friction "head" is theoretically constant for any fluid whatever. Published experiments on friction for air, water and other fluids indicate that the theory is true to the degree of accuracy required for the small friction losses to which the present correction is limited.

Friction Loss in Terms of Velocity—Friction loss for round pipes, measured as height in feet of a column of fluid $= 0.0004\ LV^2/D$.

Friction Loss for round pipes, in lb. per sq. in. $= (LV^2d)/(360000D)$.

Friction Loss in Terms of Impact Tube Reading—The Impact Pressure or Velocity Head, p_i, in inches of water, must be observed as the differential pressure between an Impact Tube, and a Static Hole in the conduit wall.

Friction Loss for round pipes, in inches of water $= 0.0257\ L\ p_i/D$.

Friction Loss for round pipes, in lb. per sq. in. $= 0.00093\ L\ p_i/D$.

Friction Loss for rectangular conduits, in inches of water $= 0.01285\ L\ p_i(a+b)/ab$.

No exact computation of change of pressure due to friction, from eddies, sudden changes of section, gradual enlargement, elbows or other irregularities is possible, and hence, pressure cannot be found when there are such occurrences between a point where it is measured and a point where it might be desired. It is to be noted that there even may be an increase of pressure due to velocity conversion at a sudden enlargement, which is, however, not capable of exact computation. There is usually negligible friction loss due to a gradual decrease of conduit area.

Correction by Bernoulli's Theorem—The foregoing corrections considered elevation, stream area and friction independently. These three items are included in Bernoulli's Theorem as used for reducing an observation at a

given point to a pressure at a different point. It is stipulated that the fluid is incompressible, or has a change of density of less than 2 per cent from the mean value. Notation:

p_1 = desired value of static pressure at a point where it cannot be measured directly, lb. per sq. in.

p_2 = actually measured value of static pressure at some other convenient point, lb. per sq. in.

h_1, h_2 = vertical height of the two points above any datum plane, ft.

V_1, V_2 = velocities at the two points, ft. per sec.

$V = \frac{\text{quantity flowing in cu. ft. per sec.}}{\text{conduit area in sq. ft.}}$

(See "Reduction in Area.")

ρ = density of fluid, lb. per cu. ft.

h_f = friction loss between the two points expressed as the height of a column of fluid, ft.

Bernoulli's Theorem has the well-known form

$$\frac{144 p_1}{\rho} + \frac{V_1^2}{2g} + h_1 = \frac{144 p_2}{\rho} + \frac{V_2^2}{2g} + h_2 + h_f$$

This results in the following formula for Pressure Reduction,

$$p_1 = p_2 + \frac{\rho}{144}\left\{\frac{V_2^2 - V_1^2}{2g} + (h_2 - h_1) + h_f\right\}$$

This formula shows three items for correcting a pressure reading at one place in order to obtain the value of pressure at another place.

Static Holes

In laying out the connections for the measurement of static pressure of fluid in motion, first consideration must be given to the opening itself, because it is there that the effects of flow have an influence. From that point on the instrument, there is no flow except that due to changes in static pressure, or to leaks.

For engineering purposes the size of static pressure holes usually should be the tap drill for ½, ⅜ or ¼ in. std. pipe thread, or ½ to ¾ inch diameter. (Smaller holes may be used if sufficient care is taken with the instrument connecting pipe as discussed in Section 10, but they are not recommended. Static pressure *researches* under proper precautions are often made with minute holes.)

Various arrangements of static pressure holes are shown in Fig. 227. A static pressure hole should be drilled *at right angles* to the surface of the wall adjacent to the fluid. *The inner rim of the hole should have no burrs or jagged edges.* This inner rim may be a smooth, square edge, or it may be slightly rounded. Slight rounding is preferable, since it makes smoothness more certain.

The average pipe fitter will screw a pipe so as to leave it projecting through the inner surface as shown at (*g*), Fig. 227. In such cases, it is very important to file the inner surface flush after the pipe has been screwed in and to remove burrs from the inner corner, or to *remove the instrument connection pipe and cut it off* so that it will be flush and smooth when replaced, as shown at (*a*), (*b*), or (*c*). In case of a static hole in a sheet metal conduit, a pipe of *larger diameter* than the hole through the conduit should be soldered on the outside, as shown at (*e*).

It is not material if the instrument connecting pipe extends only part way through the wall, as at (*a*) and (*c*). However, the thread burrs must be removed. Irregularities in the channel of the pipe to the instrument after it leaves the conduit wall do not matter, unless pressure varies rapidly.

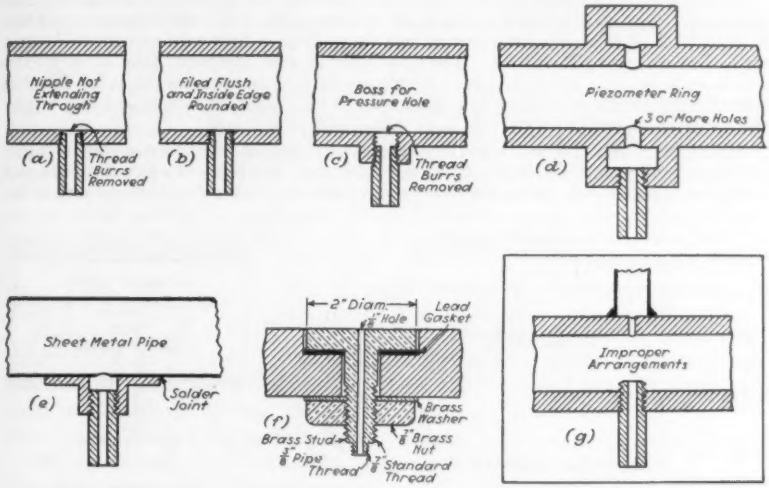


Fig. 227

Inspection of the inner end of a static hole should be made by a responsible person. Actual vision or feeling of the inner surface should be had where it is at all possible. The upper arrangement in (g), Fig. 227, shows a fortunately rare case where the static hole cannot be inspected and is probably "all wrong."

A "piezometer ring" as shown schematically in (*d*), Fig. 227, has often been used to obtain static pressure. A single pressure measuring instrument is then attached so as to give the static pressure at one point in the piezometer ring. Such an arrangement is believed to be illusory. If the static pressure differs at the different static holes, there will be flow through them in one direction or the other. There is no reason to suppose that this flow will result in giving an average value of the static pressure at the single point where the pressure measuring instrument is attached. If the flow is judged to be so irregular that several static holes are necessary, a pressure measuring instrument should be attached to *each* static hole and the *average* of the readings determined. Such an arrangement also gives knowledge of the actual variation of static pressure from point to point. If there is an appreciable difference between the individual readings, a cloud is cast upon the value of the average.

In spite of this logic, piezometer rings are used satisfactorily in difficult locations where centrifugal and other effects create variations of static pressure across a stream and where the initial cost and time required in calculations preclude the installation of more correct means, as described in the next paragraph.

In most cases, where it is necessary to take static pressure in an irregular conduit, the best that can be done is to use a number of static holes in the walls of the conduit at places where the flow is most likely to be parallel to these walls. This is for the reason that the direction of the flow is much more likely to be known near some of the walls than in the midst of the fluid. There should be a separate pressure measuring instrument for each hole and the average of all of the readings should be used. It is not possible to obtain an automatic average by connecting several holes to a single instrument. Each hole should be drilled perpendicular to the inner surface immediately surrounding it, and should not be smaller than the tap drill for ½ in. standard pipe thread. There should be approximately 1 hole for each 16 sq. ft. of conduit cross-sectional area, but in ordinary cases, not less than two nor more than six holes. However, the number of holes used must be selected according to the nature of the conduit. (See also A.S.M.E. Fluid Meter Report, Third (1931) edition, page 17).

Static Tubes

A static tube may be used to measure static pressure in the midst of a body of fluid flowing in a conduit with parallel flow, where the static pressure is constant through the body of the fluid, but usually the easiest way to obtain it is by means of a static hole in the conduit wall, so that a static tube should be rarely used.

In the case of measurement of flow by means of a traverse of an impact tube across a conduit with parallel flow, as prescribed by the National Association of Fan Manufactures and the A. H. S. V. E., it is usually convenient to take the readings of both total pressure and static pressure by means of a Pitot tube. The static holes in such approved* form of Pitot tube are known to give true static pressure. A tube may be constructed as shown at (*a*), Fig. 228 with the arrangement of the Pitot tube as shown, but with static holes only, and such a tube may therefore be used as a static tube in a conduit with parallel flow.

A static tube, as mentioned below, is very long, and a similar static tube as shown at (*b*), may be made with much less length if properly calibrated. It consists of a pipe perpendicular to the axis of the conduit, with a bend and a short tube about 8 diameters long, parallel to the

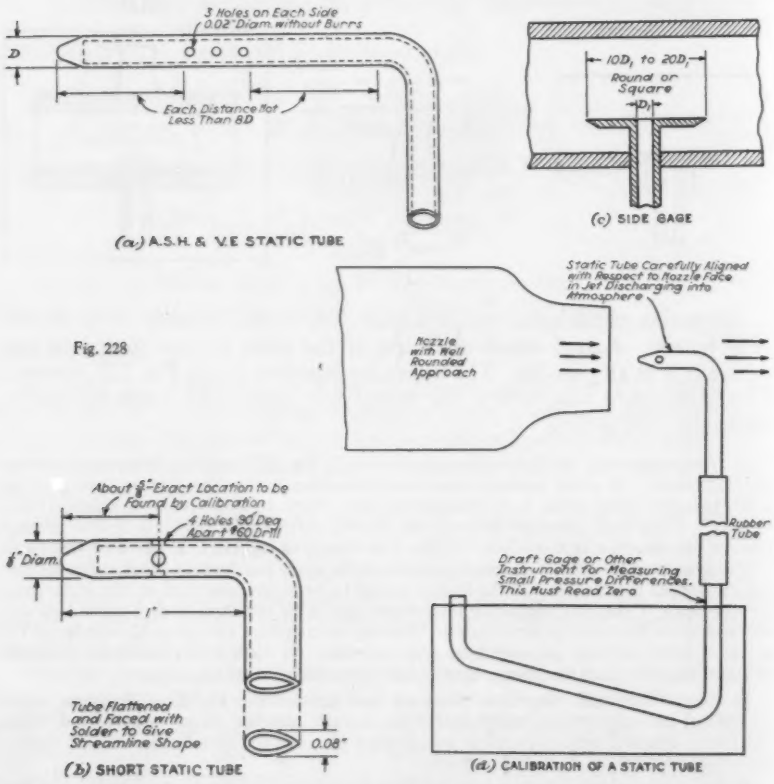

3 Holes on Each Side
0.02" Diam. without Burrs
D
Each Distance Not Less Than 8D
(a) A.S.H. & V.E STATIC TUBE
10D, to 20D,
Round or Square
D,
(c) SIDE GAGE
Static Tube Carefully Aligned with Respect to Nozzle Face in Jet Discharging into Atmosphere
Nozzle with Well Rounded Approach
About 8"—Exact Location to be Found by Calibration
4 Holes 90 Deg Apart #60 Drill
1/8" Diam.
1"
Tube Flattened and Faced with Solder to Give Streamline Shape
0.08"
(b) SHORT STATIC TUBE
Rubber Tube
Draft Gage or Other Instrument for Measuring Small Pressure Differences. This Must Read Zero
(d) CALIBRATION OF A STATIC TUBE

Fig. 228

axis of the conduit. The end of the short tube is closed by a bullet nose pointing up-stream. Holes are to be drilled in the sides of the short tube about 5 diameters from the nose, at such a point as will give true static pressure as shown by the calibration method described below. The tube is to be oriented in the stream so as to give the highest absolute pressure.

A static tube for use in the midst of a body of fluid where there is parallel flow may be a "Side Gage" as shown at (*c*). This consists of a thin plate, the outer surface of which is perfectly plane and to the inner surface of which is attached a pipe at right angles. A static hole is drilled through the plate into the pipe. The instrument is then inserted in the body of fluid with the plane face exactly parallel to the direction of flow. The plate may be either

*A.S.M.E. Standard Test Code for Disc and Propeller Fans, Centrifugal Fans and Blowers.

square or circular. Its dimension in the direction of flow shoule be about 10 or 20 times the diameter of the static hole. The edges of the plate should be chamfered on the inner face so that the fluid will flow along the plane surface without eddies or disturbance. Such an arrangement provides a surface along which the fluid flows in a parallel direction in the midst of a body of fluid. However, it is necessary to calibrate.

A static tube which will give approximately correct indications in the midst of a body of fluid where there is non-parallel flow was described by Carl J. Fechheimer in "Transactions of the A.S.M.E.," 1926, Vol. 48, page 965. Another is shown in *Mechanical Engineering*, October, 1927, page 1150.

Any form of static tube may be calibrated by the following method shown at (*d*). There is to be provided a jet of air discharging from a nozzle with a well-rounded approach. The object is to provide a jet with appreciable velocity, discharging a parallel stream into the atmosphere. It is known that the static pressure in such a parallel jet moving in the atmosphere is the same as the static pressure of the quiet atmosphere at a distance from the jet. The velocity of the jet should be some what greater than the velocity of flow in which the static tube is to be finally inserted. The static tube is to be inserted in the jet and properly aligned with respect to the nozzle axis. The end of the static tube is to be connected to a sensitive manometer, which should show a zero pressure differential with atmosphere. If not, the static tube gives erroneous readings.

Impact Tubes

An impact tube is a tube with an open end pointing directly up-stream, connected to a pressure measuring instrument, and giving Total Pressure, the sum of static pressure and pressure equivalent of velocity head, for liquids as well as gases. Proof of this for liquids has frequently been given empirically. Demonstration for gases, even with comparatively large pressure difference was first given by Dr. Sanford A. Moss.* It turns out that the fluid is brought from the velocity existing in the conduit to zero velocity immediately in front of the impact tube opening, without loss of any kind, so that the pressure accumulated in front of the impact tube is the exact value which would produce the pipe velocity. In other words, there is perfect conversion of velocity into pressure in front of the impact tube, even when there is appreciable compression of a gas.†

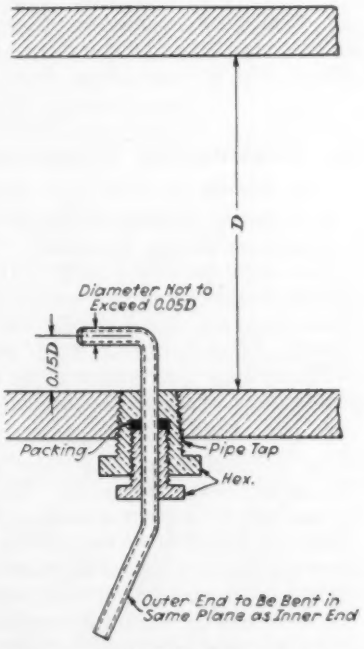


Fig. 229

An impact tube for use in cases where total pressure may be used in engineering computations (as in overall performance, efficiency, etc.) or to give total pressure in head meter work, is shown in Fig. 229. It should be inserted in the conduit so that the open end is at a distance equal to 0.15 of the conduit width from the wall. This places it at a point 0.7 of the distance from the center of the conduit to the wall, where the velocity is approximately equal

*"The Impact Tube," Trans. A.S.M.E., 1916, Vol. 38, page 761.

†A full discussion given in Bureau of Standards Journal of Research, Vol. 2, March, 1929, Research Paper No. 49 pages 567, 625, 639 and 640.

to the average value. Lengths of straight pipe should precede and succeed the tube as specified above under "Location of Pressure Openings." The outer diameter of the tube should not exceed about 5 per cent of the conduit width to avoid restriction of flow.

An impact tube in the jet discharged from an orifice nozzle can only be used if the final static absolute pressure is more than half of the initial total absolute pressure. The impact tube should have a diameter not exceeding about 5 per cent of the nozzle diameter, and should be placed so that the diagonal distance from the corner of the nozzle end to the corner of the tube end is about 0.55 of the nozzle radius, so as to give an area past the corner of the impact tube greater than the jet area.

An impact tube should be so shaped as to have the portion immediately back of the open end, parallel with the stream for a short distance, succeeded by a bend at right angle so as to lead out of the stream. The open end of the impact tube should be a smooth round tube. The shape is a matter of indifference. It is usually chamfered somewhat on the outside. However, it may be perfectly square or may be rounded. The length of tube between the open end and the bend is not material The open end must face squarely up-stream. An impact tube inserted in a conduit should have the outside end bent in the same plane as the inside end, so that it may be known that the tube is pointing up-stream.

The Pitot Tube is a combination impact tube and static tube which gives both total and static pressure through independent pipes assembled together Its treatment belongs under Flow Measurement. For recent discussion see 1931 A.S.M.E. Fluid Meter Report, pages 41-45 and 58.

10. Elimination Connection Errors—B. Connecting Lines

This section discusses tubing or piping *between* a Pressure Opening and a pressure measuring instrument.

A slight *flow* along a small diameter pipe, due to a small leak, causes a serious pressure drop and consequent error in the pressure measurement. When there is a slow leak near the instrument, the pipe should be of good diameter, often ½″ inside or ½″ standard pipe, and absolutely tight.

The average mechanic without engineering supervision will not run a pressure line which is absolutely tight.

Pressure Variations Cause FLOW—And therefore, the effects of flow in the instrument line may show up as errors in the instrument reading. This should be borne in mind. Too long a pipe between the pressure opening and the instrument introduces lag. If the pipe is liquid-filled, inertia effects are added, often magnifying pressure variations. If a large-volume air or gas chamber is used for damping, the flow through the pressure opening will become considerable at every variation, and may destroy the parallel flow motion of the fluid in the conduit in the vicinity of the pressure opening where it is most important. This is particularly true when a large-capacity instrument line starts at a small pressure opening. Another effect usually overlooked is that a sloppy job of instrument line will have unequal flow characteristics for the two directions, to or from the instrument. This is usually negligible in steam work and with a single connection, but with two non-liquid filled lines to the two sides of a differential gage, with different coefficients and different capacities, errors are introduced of such magnitude

that pressure variations in *fluid at rest in the conduit* will show up as apparent indications of rapid motion of such fluid. In head meter practice such false pressure readings are not tolerated. They should not be in "plain" pressure measurement.

A connecting pipe preferably should have no traps. If the contents are air or gas it should *slope downward*: continuously from a high point to the main at one end and to the pressure measuring instrument at the other end; or the high point may be at either end. If the contents are liquid, the pressure pipe should *slope upward*, from one low point to each end, with precautions given later regarding a gas pocket at the instrument. Accumulation of liquid or gas pockets from some unexpected source often collect in a trap and falsify the pressure reading.

Liquid will not drain nor gas bubbles rise by gravity in a pipe with less than ½" inside diameter.

Screwed Pipes may be ¼", ⅜" or ½" standard brass or iron pipe. One-eighth inch pipe is difficult to make tight, and drains poorly. Assemble with pipe thread compound, shellac, red lead, or white lead, taking pains not to plug the line with excess compound. As close as practicable to the pressure opening, install a valve with gland on instrument side, (or section of rubber tube with pinch-cock). To test tightness, close off and see if the instrument holds its reading. In many cases, this test will show a serious leak. If a pipe carries a vacuum, a leak may be stopped by painting over the pipe and joints with shellac or asphaltum varnish. If a pipe carries air pressure, a leak may be found by painting with soapsuds. If a pipe carries steam above atmospheric pressure, a leak may be found by painting with thick cylinder oil. If a pipe carries liquid above atmospheric pressure, leaks will show on careful visual inspection and of course should be eliminated.

Rubber Tubing may be used for vacua or pressure up to about 20 lb. per sq. in. It should not be less than $\frac{3}{16}$" inside diameter, with a wall not less than $\frac{1}{16}$" thick. Thicker walls are preferable, especially for vacuum. The rubber should be "live"—elastic and new. Nipples or glass tube ends should have a diameter appreciably greater than the inside diameter of the rubber tubing. For pressures greater than ¼ lb. per sq. in. or 6" water column, tubing is preferably slipped on nipples with shellac. For pressures greater than 10 lb. per sq. in., tubing is preferably retained by wire-winding.

Cleaning Rubber Tubing—This is especially necessary in high vacuum work. Immerse for twenty-four hours (or less when fairly clean) in a boiling solution of dilute caustic soda, wash with distilled water and alcohol and dry by passing a rapid current of clean dry air through the tube to get rid of sulphur dust.

Copper Tubing, $\frac{3}{16}$" to ½" inside diameter, may be used for moderate pressures. It is desirable to use a single length of tube with ferrules only at the two ends, rather than a number of short lengths with couplings. Careful inspection of tube, ferrules and couplings is usually sufficient to insure tightness. However, it is sometimes desirable to have a short section of rubber tube close to the pressure opening, for the tightness test specified above for screwed pipe.

Glass Tubing for vacua or pressures up to about 20 lb. per sq. in. may be of ¼" inside diameter with rubber tubing connecting joints and forming bends. This gives positive knowledge regarding liquid or gas pockets. Glass tubing is best washed with nitric acid. See Chapter XI.

Contents of Instrument Connecting Lines—It is imperative that the exact contents of the pipe be known, whether liquid, air or gas, and without possibility of pockets.

A "*Bleeder*" for getting rid of liquid, air or gas pockets, is formed by use of a tee, with a plug or a valve at the outlet, or by insertion of a union coupling in the line which may be temporarily loosened. A bleeder located immediately at the instrument may be merely provision for temporarily disconnecting or unscrewing the instrument. A bleeder for air pockets must, of course, insure flow of liquid to the pipe beyond the bleeder.

For pressure measurement with air and non-condensible gases, or for vacuum measurement in any case, unexpected liquid pockets may occur in the measuring line from moisture collection, oil gasoline, liquid blown from U-tubes, liquid remaining in old pipes, etc., which give errors unless positively prevented. Three good set-ups are as follows (they give the gage pressure at the level of the pressure opening and the difference of level between this point and another pressure gage, or the center line of the machine, apparatus, etc., must be allowed for).

(1) A ¼" or larger pipe, with a bleeder, with a vacuum or pressure more than 2" of mercury different from atmosphere. For a U-tube ,the bleeder may be at any nearby point (because liquid in it may be seen or removed) but for any other gage, the bleeder must be immediately at the gage. Occasional opening of the bleeder will purge the line. If there are any traps, it must be certain their height is not too great to prevent purging of the line by the existing pressure or vacuum.

(2) Drainage reservoir with a ½" pipe sloping to it from each end. A drain cock in the bottom is opened occasionally. For the case of a vacuum there must be in addition, a valve between reservoir and instrument line, closed during the draining period.

(3) Seal Pot—½" pipe line sloping downward from each end to a vertical drain pipe at any convenient place, dipping in a pot filled with liquid to a depth sufficient to safely seal the existing pressure or vacuum.

For measurement of pressure above atmosphere (liquid or steam) the object to be attained is elimination of all pockets arising from air initially in the pipe, or liberated from the liquid, so that the pipe and gage will be filled with liquid. Correction must of course be made for the head of liquid in the pipe between the levels of the gage and the pressure opening. For steam and a Bourdon gage, there must be sufficient length of pipe, or a specially provided coil adjacent to the gage, to be sure that condensate and not live steam enters the gage. Time must be allowed for steam to condense and fill the instrument line or the condensation must be hastened by cooling, or the pipe must be filled with water in advance. For steam, there must be a high point immediately at the main or measured apparatus to prevent drainage of condensate. A good set-up is as follows:

A ¼" or larger pipe with a bleeder at the instrument. Preferably a single low point with the pipe sloping upward to either end. Flow through the bleeder must be vigorous enough to insure the forcing through of air pockets in any traps. For liquid which may have air entrapped, the pipe should slope upward everywhere from main to instrument, or should be ½" pipe with a single low point sloping upward either end.

Instrument Seals—The above has not considered the additional problems introduced when the fluid, whose pressure is to be measured, is to be sealed off beyond all doubt from the diaphragm, hollow spring or other parts of the instrument. Various sealing devices are on the market and the best procedure is to specify one at the same time as the instrument itself, bearing in mind the necessity for avoiding *variable* liquid head corrections which would falsify pressure measurement.

The Position of Cathode Ray Instruments in the Field of Oscillography

*O. Ackerman**

THE two principal types of apparatus used in electrical oscillography are the moving coil and the cathode ray instruments. The moving coil instruments, known under various names (Osiso, Multi-element Oscillograph, Instantaneous Watt-meter, etc.) require for their motor and lamps only a low voltage (6 volts), operate on simple electrical and mechanical principles and are in general easier to handle than cathode ray apparatus. Their voltage and current sensitivity is very high, up to $\frac{1}{16}$ inch per millivolt or $\frac{1}{2}$ inch per milliampere. Their "time" sensitivity, however, is limited by the inertia of the moving coil (mirror and vibrator strips) and of the photographic film and its moving mechanism. In the present state of the art the moving coil instrument can reproduce practically undistorted oscillations up to 5000 cycles per second.

Although the cathode ray instrument can perform most tasks for which the moving coil instrument may be used (except perhaps where very high voltage and current sensitivity or the recording of "instantaneous" watts is required), the proper field of the cathode ray instrument starts where the limitations of the moving coil instruments are reached i.e., in general—

(a) In the recording of high frequency phenomena (over 5000 cycles per second),

(b) In the study of single phenomena (occuring at random) where the phenomenon itself must start the process of recording within less than 1/50th of a second,

(c) In measuring voltages with negligible loss of power (electrostatic methods),

(d) In the direct recording of relations where the abscissa is not time, but current, field strength, or any other electrical quantity, as for instance in hysteresis or voltampere curves.

(e) In cases where good visibility of the registrations of the instrument is required, for instance in lectures or in control rooms.

Of course the whole range outside of the limits of the moving coil instruments cannot be covered by one particular cathode ray apparatus. Therefore, various types of the latter have been developed which differ mainly with regard to intensity of record and to sensitivity.

The sensitivity (deflection per volt or ampere) is the higher, the lower the cathode voltage.

The intensity of the trace on fluorescent screen or photographic film is the greater the higher the cathode voltage, since the latter determines the speed with which the electrons impinge upon the sensitive layer.

The deflection of the electron jet is usually produced by the electrostatic field between a pair of condenser plates; it is given by the relation

*Supply Engineering Department, Westinghouse Electric & Manufacturing Co.

PRINCIPAL PROPERTIES OF VARIOUS CLASSES OF CATHODE RAY INSTRUMENTS

Cathode Voltage	300	3000	3000	30,000	60,000	60,000 and above
Cathode type	heated				cold	
Structure of Housing	glass		metal			
Recording	Recurrent Phenomena			Practically all phenomena		
		Transients up to 20,000 cycles.	Transients up to 100,000 cycles.			
Photographic Film	Outside		Inside			Outside through Lenard window.
Remarks	Life of filament = life of tube.		Frequent replacement of Filament.		Comparatively expensive high voltage supply.	
		Recurrent phenomena well visible on screen to audience. (For demonstrating purposes.)		Range and practicability of heated cathode and of Lenard window instruments not sufficiently well established. As a matter of fact, practically all research work on highest speed transients has been done with plain cold cathode instrument with inside photography.		

$$\frac{1}{2V}\,\frac{1}{d}\,A = \text{deflection per volt}$$

where

$$V = \text{Cathode voltage}$$

$$\left.\begin{array}{l} 1 = \text{length} \\ d = \text{spacing} \end{array}\right\} \text{of deflection plates}$$

A = distance between the center of the deflection plates and the recording screen or film.

Normally the ratio 1/d lies between the values 4 and 8, and the distance A measures from 12 to 20 inches (30 to 50 cm). With these physical dimensions more or less fixed, the volts per cm deflection are a function of V and may in general be from 1/60 to 1/200 of the cathode voltage, the smaller fractions applying to the larger instruments.

The difference in intensity of record and in sensitivity are in a certain way tied up with the structure of the instrument whose envelope may consist of a permanently sealed glass tube or of a metal case. The latter type can only be operated in connection with a set of vacuum pumps even if the records are taken by means of outside photography.

The following table gives an outline of the principal properties of the various classes of cathode ray instruments according to the present state of the art. It must be borne in mind, however, that limits can not be drawn sharply and that special skill and development may make an instrument useful in a range where it now is not practical for ordinary engineering applications.

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When writing to the above company, please mention INSTRUMENTS

New Model Viscosimeter

(C. J. Tagliabue Mfg. Co.)

THE Saybolt Standard Universal Viscosimeter is one of the oldest and most widely known and used instruments for testing petroleum oils.

It was designed many years ago by the late George M. Saybolt. It has proven, by reason of years of service its value as the simplest, most accurate and most practicable instrument for testing the viscosity of lubricating oil. While the old instrument was satisfactory, it was admittedly lacking in certain desirable features, among which may be mentioned motor stirring instead of hand stirring and automatic temperature control.

The new thermostatic viscosimeter keeps all of the advantages of the old apparatus and yet embodies many new and desirable features. These new features are important from the standpoint of convenience. They mean that more accurate determinations can be made and that much less time is required in making a test.

Some of these new features are as follows: The temperature of the bath is held constant within ± 0.1°F. at any test point between room temperature and 220°F. One of the troubles which is usually experienced with a thermostatic bath is that of setting to the correct temperature. The new thermostatic system allows easy setting by means of a pilot lamp which indicates whether the contacts are open or closed by the appearance of the lamp. A flickering light seen from any point of the room shows that the bath is being controlled and operating properly. Sticking contacts are prevented by one contact being oscillated by means of a cam on the propeller shaft. The heating coils are inexpensive and easily replaced. The tubes at both top and bottom are accessible. The bath heats rapidly to any test point and the oil is used instead of water as a liquid. The stirring is adequate and insures uniformity of temperature and maintains the proper difference between the tube temperature and bath temperature required by the American Society for Testing Materials. The original Saybolt Standard Viscosimeter tubes either with or without Universal Furol orifices are retained.

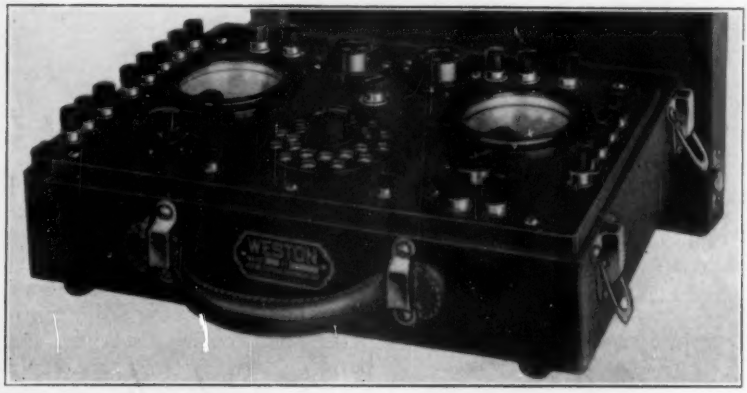
NEW INSTRUMENTS

Recently Developed by Instrument Manufacturers

Write Information Section, Instruments Publishing Co., Pittsburgh, Pa., for additional Information.

Model 565 Radio Equipment Tester

(Weston Electrical Instrument Corporation)



THE instrument equipment consists of three 3¼" Weston instruments: 7 range A.C. Model 476 for 1000, 200, 16, 8, 4 volts, 4 amperes and 100 milliamperes; 12 range D.C. Model 301 for 1000, 250, 100, 50, 25, 10 volts, 0-100,000/-0-10,000 ohms and 100/25/2.5/1 milliamperes; and a triple range D.C. Model 301 for 100/20/2 milliamperes. Shunts may be obtained to increase the 20 ma. range to 2 or 10 amperes. The various ranges of the D.C. volt-ohm-milliammeter are controlled by a 23 point-bi-polar switch with colored index markings. The ranges of the A.C. meter are controlled by a 9 point bi-polar switch. A toggle switch is used to change the ranges of the D.C. milliammeter.

Three tube sockets are provided on the instrument panel, a UX, a UY and an oscillator tube socket. The set is completely self-contained and housed in a strong oak case with a snap-on cover, its principal dimensions are 13½ x 11¼ x 4¼ inches and it weighs 16 lbs.

Tests with Tester Plug Inserted in Radio Set—All filament voltages; all heater voltages; cathode voltages; four bias voltages; two control grid voltages; two plate voltages; three plate current ranges; bias voltage on D.C. sets with reversed filaments convenient readings of both plates of rectifier tubes; two screen current ranges.

External Tests that can be made with Model 565—Measurement of power transformer up to 1,000 volts A.C.; line voltage measurements on the A.C. meter; heater voltage at power pack—three ranges on A.C. meter; plate current at "B" supply taps—three ranges on D.C. milliammeter; "B"

supply at power pack—four ranges on D.C. voltmeter; "A", "B" and "C" battery voltages—six ranges on D.C. voltmeter; continuity tests—using self-contained 4½ volt battery and the D.C. voltmeter with a resistance of either 1000 or 100 Ohms per volt as desired; resistance measurements—the D.C. voltmeter also serves as a direct reading ohmmeter with ranges of 0-10,000 or 0-100,000 ohms, condenser measurements can be made from ¼ to 6 microfarads; tube checker—for all filament and heater type tubes—checker operates directly from any 50 to 60 cycle, 90 to 135 volt A.C. line, imput to radio set—on 4 ampere A.C. range and small A.C. measurements such as currents in voice coil of speaker, etc., using the A.C. 100 MA. range; filament or heater current of A.C. tubes on 4 ampere A.C. ammeter; R.F. oscillator—three frequencies—for neutralizing and synchronizing and testing radio sets when no broadcast signal is available.

Model 563 D. C. Circuit Tester

(Weston Electrical Instrument Corporation)

THE Model 563 is an instrument for checking resistance values and continuity of circuit during the process of manufacture and for service and installation work on many types of electrical apparatus. A few typical examples are as follows: telephone apparatus and circuits; radio transmitting and receiving sets; fire and burglar alarm systems; household electrical applicances; ignition systems of automobile, motor boat and airplane engines; small electric motors and transformers; electric refrigerators, oil burners, etc.

This model is a compact, completely self-contained portable instrument. It is accurate within 2%. Its equipment consists of a Weston Model 301, 3¼ inch diameter meter having two resistance ranges—5,000 and 50,000 ohms—mounted in a black Bakelite case with a Bakelite panel; a toggle switch for range selection; a self-contained 1.5 volt flashlight cell (Everready Cell No. 935); a leather strap carrying handle and a pair of 30-inch leads with test prods.

A feature of this instrument is a voltage adjuster located at the top of the instrument case to compensate for change in potential of the self-contained battery. To make this compensation it is only necessary to short circuit the binding posts and adjust pointer to zero ohm position on the scale by turning adjusting screw.

Dimensions: 5½ x 3⅝ x 2⅞ inches. Approximate weight: 2 pounds. Range 5,000/50,000 ohms.

New Model Micro-Metallograph

(*E. Leitz, Inc.*)

THE Leitz Works have introduced a new model of their large micro-metallograph which embodies many special features of importance. The new development incorporates changes in mechanical features as well as in optical construction.

Amongst the mechanical factors involved in the new construction are: the microscope stand is of much heavier design and consequently far more rigid than the previous construction, which is an important factor in high powered work and in photo-micrography. The object stage is of increased size, mounted in a most solid manner to the stand proper. Of utmost importance is the fact that the fine adjustment is enclosed in a separate housing provided with air space to protect the micrometer screw against any external heat influence. It insures focus of objective to an extent as permits the operator to maintain the minutest accuracy in this field of endeavor. At the same time, any heat influence upon the microscope mechanism is entirely avoided for the reason that the entrance tube of the vertical illuminator is equipped with a circular reflecting mirror. Thus all rays emanating from the light source not required for actual illumination are reflected away from the vertical illuminator.

In optical features, the construction is provided with an ingenious device as will materially increase the flatness of the micro image. This combined with the use of Periplan oculars of Leitz manufacture offers everything that is to be desired in photo-micrography and visual observation. The stand which supports the microscope is provided with a cabinet fitted with three

drawers which serve for storing specimens and accessories.

The Leitz Works now have under construction a Differential Dilatometer which can be utilized with the micro-metallograph. Another important accessory for use with the micro-metallograph is a device now nearing completion in the form of a darkfield illuminator affording examination of metal specimens not heretofore attempted.

Test Oscillator

(Burton-Rogers Company)

THIS instrument combines a variable frequency oscillator with a range of 1500 to 550 Kc. with fixed frequency oscillators of 175 and 180 Kc. with a vernier for the variations required for aligning i.f. stages of super-hetrodyne receivers. It is equipped with an output meter for visually indicating resonance. It operates on 110 volts A. C. 60 or 25 cycle or 110 volts D. C. or external batteries for filament supply and on one small B battery for plate supply. A compartment is provided for the B battery. The signal intensity may be varied over wide limits.

The instrument is completely shielded and is mounted in a durable carrying case. Special leads and complete instructions are furnished. Tube and battery not furnished.

Type 561 Portable Resistance Tester

(Hoyt Electrical Instruments Works)

THE resistance tester is a direct-reading ohmmeter with a self-contained battery together with test-leads. It has a host of uses on the radio service bench. The tester is equipped with small flashlight dry cells, similar to the Burgess Unit No. 1., which may be obtained anywhere. Replacement is easily made by removing the bottom plate of the tester.

The instrument is equipped with an adjusting shunt which compensates for the drop of voltage in dry cells under use. By means of this, the battery may be used for several months without reloading.

The Promi Microscopic Drawing and Projection Apparatus

(Clay-Adams Company, Inc.)

THIS microscope should find many applications in science and industry for visual examination, comparison and recording. It can be used for the inspection of raw material, partly processed and finished products. For example for the examination of pulp, paper, textile and other fibres; for inspecting fabrics if not too closely woven, etc. Flaws easily overlooked by the naked eye are readily detected.

Fig. 1

1. Objective holder (Standard thread)
2. Objective
3. Focusing screw for objective focusing
4. Stage clips for holding specimen slide
5. Stage (This stage is hollow allowing for air-cooling or water-cooling by means of rubber connections as shown)
6. Clip to hold rubber tubes to prevent water or air from flowing out of stage
7. Condenser
8. Condenser housing for lamp
9. Condenser adjustment screw
10. Knob to assist in moving condenser housing when releasing screw 9.
11. Lamp housing
12. Lamp adjustment screw (Vertical)
13. Lamp adjustment screw (Horizontal)
14. Electric cord leading to rheostat
15. Horizontal supporting rod
16. T supporting rod joint
17. Release lever for adjusting apparatus at any angle from horizontal to vertical position, or inverting
18. Thumb screw for moving apparatus vertically on supporting rod
19. Vertical supporting rod fastened to sturdy base
20. Base
21. Thumb screw on base
22. Tube (standard size) with 5x ocular (used to obtain higher magnification in drawing and projecting also used as eyepiece when Promi is inverted for use as a microscope.
23. Mirror (used with tube and ocular to reflect object on table for drawing, or on screen when apparatus is in upright or inverted position, also used as light reflector when Promi is used as a microscope).
24. Micro-Cuvette for projection of living organisms
25. Insect holder for projecting whole objects without special mountings

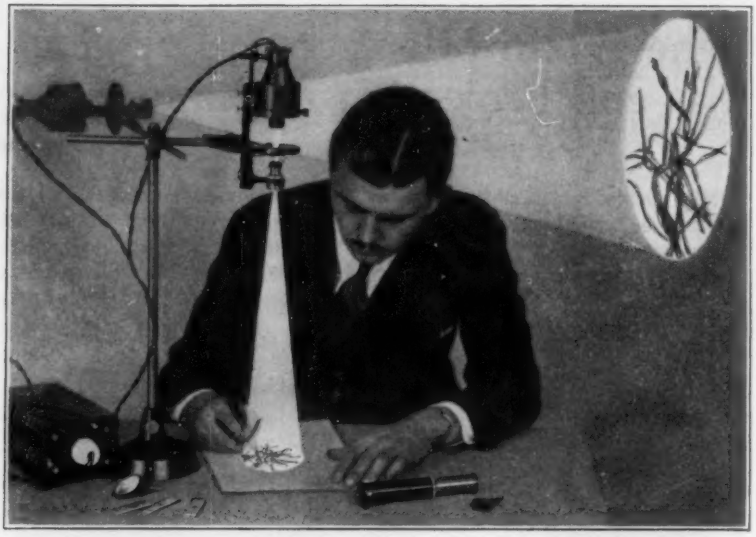


Fig. 2

The apparatus is simple to set up and easy to manipulate. It swings readily from vertical to horizontal position on a swivel rod. It has a simplified illuminating system-strong filament bulb of low voltage, automatic in operation, free from fluctuation and constant in intensity-advantages not possible with arc light illumination. The light source is enclosed in a metal housing and the proper adjustment of both light and condenser is facilitated by use of swivel and sliding joints. The object stage is hollow for continual water cooling. Ocular and tube are furnished for high power magnification, and both objectives and eye pieces are of the standard microscope type. Rheostat can be used with both AC and DC current and for both 110 and 220 volts. A specially constructed tank makes possible projection of living organisms in fluid. It can be used in the ordinary lighted room for low power work. For drawing purposes it will enlarge to 1400 times at a distance of 6 feet.

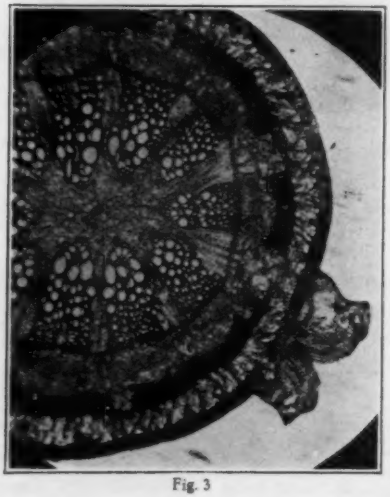


Fig. 3

Used as a projection apparatus it is possible for one or more persons to clearly and conveniently examine specimens and samples projected on a table or wall, eliminating the eyestrain and disadvantage of individual microscopic examination.

Fig. 2 shows how a specimen is projected on paper enabling the enlarged image to be drawn in precise detail by simple tracing where a permanent record is desired. This is useful for enlarged

drawing and designing. Higher magnification may be obtained by using tube and ocular and/or high power objectives.

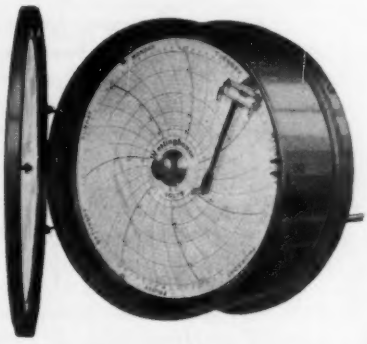
The apparatus is easily converted into a compound microscope. Higher magnification is possible by the use of standard microscopic high power objectives.

Microscopically enlarged specimens can be photographed without the use of a camera (see Fig. 3).

A polarizer and analyzer attachment can be supplied, making it possible to study crystal sections.

New Recording Instruments

A NEW circular chart recording instrument, identified as Type A, has been announced by the Westinghouse Electric and Manufacturing Company. These instruments are light and small; they include ammeters and voltmeters; and are made for switch-board mounting or as portable instruments.



These instruments have numerous applications in industry, an example of their utility is their use for determining the most economical use of motor-driven machinery, the loading of motors, time of starting in mornings or after lunch hour, time of quitting, loss of time, and power required for different operations or depth of cuts.

They are designed principally for alternating-current applications but are also applicable to certain direct-current services. The ammeters are available in sizes ranging from 5 to 50 amperes, and give a full-scale reading from zero to the value at which the meter is rated; the voltmeters are made in ratings varying from that which provides a scale of from 90 to 140 volts to that which records a maximum voltage of 550 volts.

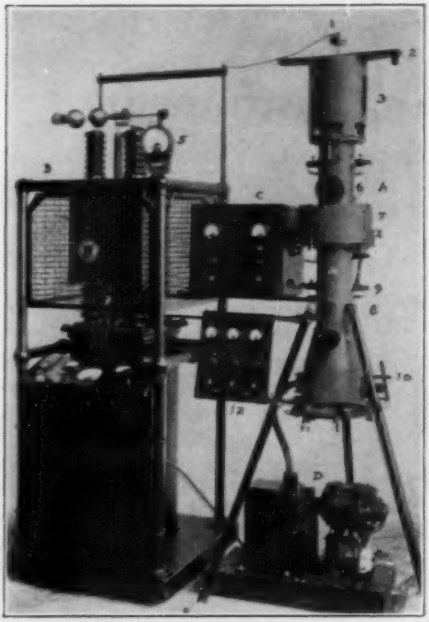
This instrument uses for the measuring unit a small motor structure, in which a laminated armature core or "rotor" is mounted in the field of an electromagnet. The air gap surfaces of the pole pieces are arranged to give as uniform a scale as is consistent with good performance at light loads. No delicate pivots or jewels are used for bearings. The control force is provided by heavy springs. The main shaft operates the pen directly, and the mechanism as a whole is damped by means of an aluminum disk arranged to swing in the air gaps of a powerful set of permanent magnets.

Three kinds of clocks for moving the circular chart are provided; a key-wound, 8-day clock for driving the one-week charts; a key-wound, 36-hour clock for driving the one-day charts; and a sub-synchronous (self starting) motor-driven clock, operated by the system frequency. Change gears are available to change synchronous-driven meters to other speeds.

Cathode Ray Oscillograph Equipment

(Westinghouse Electric & Mfg. Co.)

THE Westinghouse Cathode Ray Oscillograph belongs to the 60 kv. class applying inside photography. The history of the instrument is given in the paper "A Cathode Ray Oscillograph with Norinder Relay" by O. Ackermann, in the A.I.E.E. Journal of April 1930, or in the Transactions, Vol. 49, page 467.



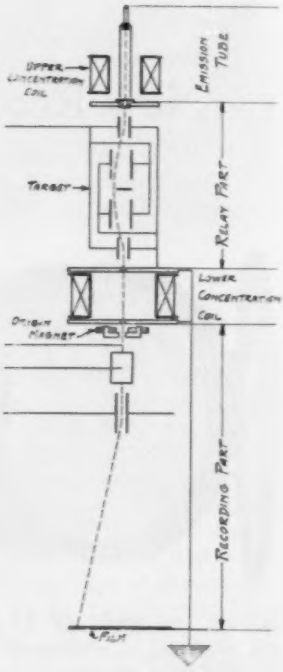


Fig. 1. Cathode Ray Oscillograph Equipment.
Fig. 2. (right) Plate and Coil System of Cathode Ray Oscillograph.

The complete equipment is shown in Fig. 1. It consists of:

A. The Cathode Ray Oscillograph
B. The High Voltage Supply
C. The Timing (Synchronizing) Device
D. The Vacuum Pump Set

Detail parts are:

1. Cathode
2. Lever, adjusting cathode ray beam exactly on center line of instrument (glass tube in flexible joint).
3. Magnetic shield around glass tube.
4. Leak valve for adjusting pressure and therewith Cathode Ray current, the latter being read on milliammeter
5. 2 MA. ammeter in ground connection to high voltage source.
6. Relay part with window for observing adjustment.
7. Concentration coil.
8. Recording part
9. Porcelain bushings with plate adjusting mechanism.
10. Lever for operating fluorescent screen and shutter.
11. Operating mechanism for roll film and counter.
12. Control panel for concentration and deflection coils.

A. The Cathode Ray Oscillograph.

The housing of the cathode ray oscillograph consists partly of steel casting, partly of seamless steel tubing. All parts and pumping connections are joined by steel or brass flanges between which rubber gaskets from ½ to ¾ inch in width are clamped. Conical greased joints are used at the film

moving mechanism and at the devices for adjusting the spacing between deflection plates. The cones are of small diameter and amply long to assure airtightness.

The cathode ray emission tube is of the "cold" cathode type, the cathode itself consisting of an aluminum plug. The glass tube is seated in a pliable rubber packing so that the electron jet can easily be adjusted on the center-line of the instrument through the Micarta lever (2). A voltage of 50 to 60 kv. can be applied continuously to the cathode, producing a tube current of about ½ milliampere. The vacuum is adjusted for this particular discharge condition by means of a leak valve (4). The proper vacuum is about 7 microns. A vacuum gage is not needed, since the pressure always can be judged by the ammeter reading or—at higher pressures—by the appearance of the discharge in the glass tube. A diagram of the system of deflecting plates, magnets and concentration coils is shown in Fig. 2. The deflecting plates in the relay part are arranged so that the electron jet is bent around the target and directed into the recording part of the instrument when a voltage from 1000 to 3000 volts is applied to them. Otherwise, the cathode ray beam is blocked completely by the traget. Under this condition the photographic film can be exposed in the instrument for any length of time without danger of fogging.

In the recording part of the instrument, two sets of plates with adjustable spacing provide the means for deflecting the beam in accordance with the measured quantities. An electromagnet allows shifting of the origin to any point on the fluorescent screen or film.

The internal parts of both the relay tube and the recording section are mounted on rigid frames which can easily be removed from inside the instrument.

Two concentration coils afford sharp focusing of the beam. They are, together with the origin magnet controlled from the panel (12). The oscillograms can be observed on the fluorescent screen which can be turned by the lever (10) so that the photographic film is exposed. The film holder can take a 12-exposure 3¼ x 5½ Kodak roll film, although preferably the 6-exposure special Eastman "Process" roll film is used. Oscillograms taken with this instrument are shown in Fig. 4.

B. The High Voltage Supply.

A 65 kv. rectifier supplies the cathode voltage. The two rectifying tubes, high voltage and filament transformer are mounted in an oil filled tank. The tank cover carries a 65 kv.—.008 mfd. condenser, safety gap and measuring sphere gap. In front of the tank, a control box with an induction regulator, rheostats and meters is arranged. Tank and control box are mounted on a base provided with heavy casters, and are surrounded by a pipe frame with screens affording protection against the high voltage. The unit is believed to be the most compact and sturdily designed rectifier for this voltage range.

C. Time and Synchronizing Device.

In order to avoid fogging of the photographic film, care must be taken that the cathode ray beam remain in the recording part of the instrument only as long as necessary for making the record.

The time is controlled by the potential at the relay plates which is furnished by the 6 kv. rectifier of the timing device and applied to the relay ordinarily by causing the double gap G (Fig. 3) to break down. This is

done by a small impulse of either polarity, originated in connection with the phenomenon which is to be measured.

The same voltage which operates the relay can be used for producing the timing sweep.

The oscillograms of Fig. 4 are taken with such a circuit.

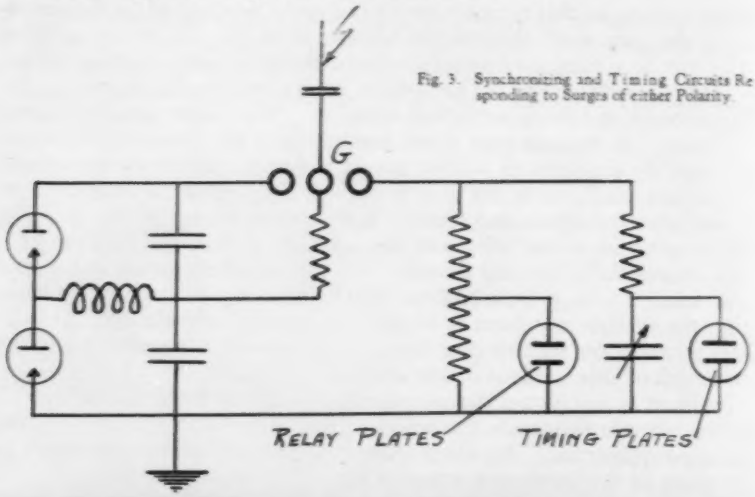


Fig. 3. Synchronizing and Timing Circuits Responding to Surges of either Polarity.

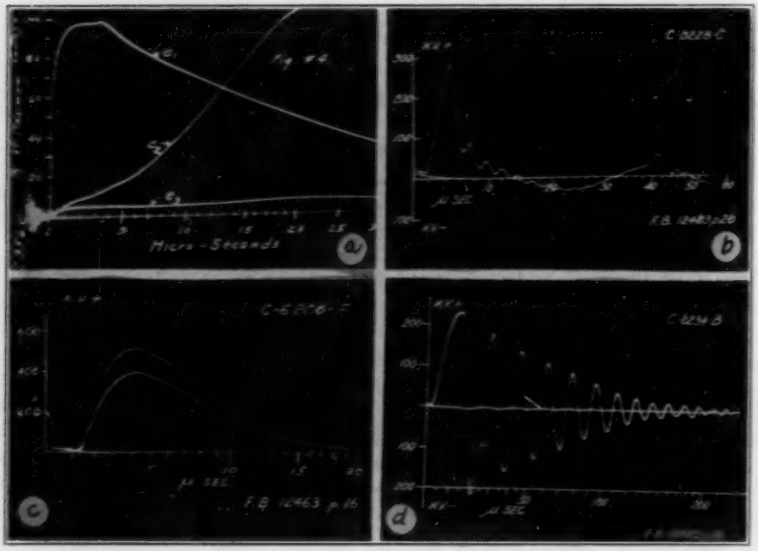


Fig. 4. (a) Oscillogram taken from Tests on Choke Coils. (b, c, d) Oscillograms taken from Lightning Tests on Sub-stations.

D. Vacuum Pump Set.

The vacuum pump set consists of a Megavac pump (Central Scientific Co.), a Molecular pump (Fig. 5), and the necessary valves (rubber sealed). The pumping set can reliably produce a lower vacuum than that necessary for the operation of the oscillograph. Mercury vapor pumps and cooling

systems are not necessary. The pumping time is 10 to 15 minutes. The degree of vacuum can always be judged from the condition of the discharge in the emission tube and from the reading of the tube current ammeter. Thus a special vacuum gage is not required.

E. Operation and General Characteristics of the Westinghouse Cathode Ray Oscillograph Equipment.

The rectifier voltage (between 50 and 65 kv.) is applied continuously to the cathode, and the air pressure is regulated by means of the leak valve so that a current from 0.3 to 0.5 milliamperes is flowing. The axis of the emission tube and the concentration coil currents can easily be adjusted so that a sharp fluorescent spot or line is obtained on the screen. The various deflecting plates can quickly be grounded and then reconnected to their circuits by means of small switches attached to the bushings (see Fig. 6). These features render it very easy to check the zero point, axis, and coordinates of the instrument during operation and add considerably to the ease and accuracy in the performance of oscillographic measurements.

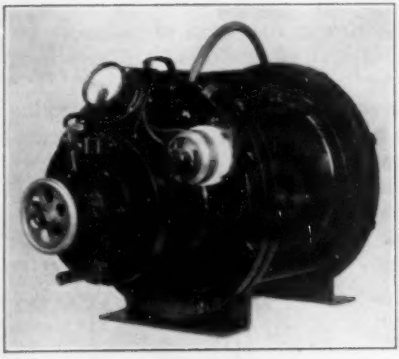


Fig. 5. Molecular Pump with Valves

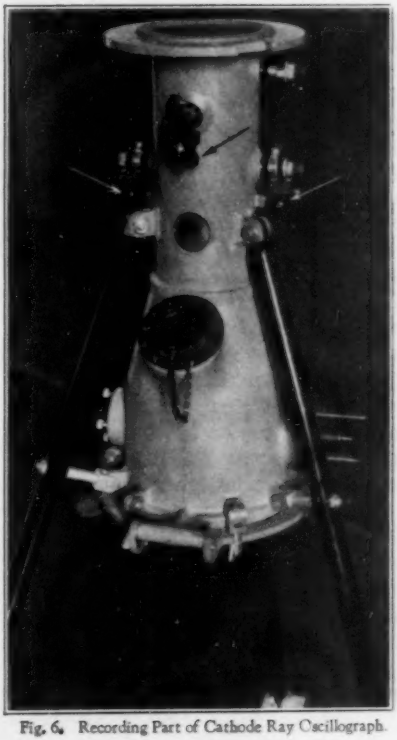


Fig. 6. Recording Part of Cathode Ray Oscillograph.

In research laboratories the cathode ray oscillograph is not only used as a pure measuring instrument, but it often is itself made an object of investigations and experiments (studies on various designs of cathode ray emission tubes, on discharges in vacuum in general, on the properties of the electron, etc.). The Westinghouse oscillograph with its simple and rigid structure, with its heavy flanges and rubber seals, is well adaptable to various kinds of experiments. The only fragile part is the 1″ diameter 15″ long straight glass tube between cathode and anode. It can easily be replaced.

Certain parts of the equipment may readily be used for purposes or with apparatus other than those described above. This applies particularly to the 65 kv. rectifier and the recording part of the cathode ray oscillograph shown in Fig. 6. The latter consitutes an oscillograph of the Du Four type if

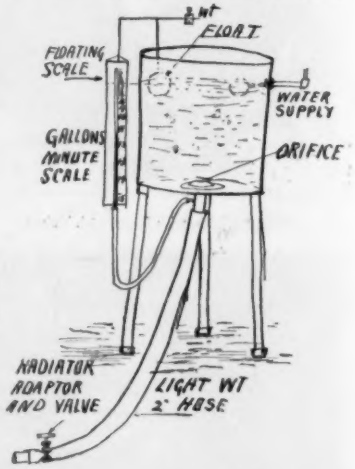
assembled with the Westinghouse cathode part (items 1 to 4, on Fig. 1), or with any other emission tube that can be adapted to its top flange.

The complete oscillograph equipment requires about 4 x 6 ft. floor space. Rectifiers and pumps operate on 110 volts, 60 cycles; the concentration coils can be furnished either for 110 volts DC or for a 12 volt battery.

Flow Meter Simplifies Radiator Testing

A SIMPLE device for testing the correct operation of radiators for automobiles, trucks and tractors and motor-boats, has just been devised by the Meriam Company.

Correct and adequate flow of water through the radiator and cooling system is essential if the engine is to run at its most efficient temperature. Up to the present time, there has been no quick way of finding out if the passages of the radiator are blocked, except where the condition was so bad that steam blew out of the top—an uncertain method at best.



The new device provides for easy and rapid testing of any type of radiator. The device consists of a 110-gallon tank, a Meriam floating flow meter and a very flexible 2-inch hose-pipe for connecting up to the radiator to be tested by means of a slip-on adapter. The valve for the control of the water flow is a simple and light aluminum screw clamp which collapses the hose against a rubber saddle vulcanized to the inside of the control point.

A special discharge orifice is built into the bottom of the tank, and a small rubber pipe connects from the outlet side of this orifice to a flow meter manometer, or flow indicating tube. The flow-indicating tube and its five-foot plainly marked scale are mounted on a float in the tank itself. By this method, the height of the water in the glass tube will always slow the correct flow in gallons per minute irrespective of the water level in the tank. An ordinary closet valve connected to the water supply refills the tank after use.

To make the test, the hose is connected to the top outlet of the radiator, the bottom outlet being left wide open. The screw clamp valve on the hose is then opened up until the radiator is full without running over. The rate of flow is read off from the flow-tube scale directly in gallons per minute. Comparison with the standard radiator chart shows immediately whether the radiator passages are blocked—and if so, to what extent.

To the garage and service station of fair size, this device has many practical advantages—not the least of which is that the customer may be convinced as to whether or not flushing or repair service is needed. To the fleet owner or tractor operator it is particularly useful because a blocked radiator may cause trouble under conditions where serious inconvenience and loss would result.

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ECONOMY IN INDUSTRY. Bulletin G-10 is issued for the information of all who may be directly or indirectly interested in knowing how modern industry is saving thousands of dollars in time, labor and material through the centralized control of all units of production. It describes and illustrates different instruments and their particular use in various buildings and plants. Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.

MEULLER BRIDGE. Catalog No. 80-Z describes and illustrates the Mueller Bridge which is a high precision electrical instrument used for determining temperatures. It is a convenient instrument for checking the accuracy of thermometers and other various high-precision measurements of temperature that must be made from time to time in operating a power plant. Leeds & Northup Co., 4901 Stenton Avenue, Philadelphia, Pa.

LIST PRICES. This September 1930 leaflet gives the list prices to be used with Bristol's Catalog No. 4000. The Bristol Company, Waterbury, Conn.

THE TECHNICAL INSTRUMENT BULLETIN. Vol. 2, No. 6, September 1930, pages 81 to 95 contains an article entitled "On Microscopic, Photographic and Other Apparatus for Wood Research, by Max Wolff, Ph.D. Emil Busch Optical Co., Ltd. 37-38 Hatton Garden, London, E. C. I. England.

FUSES. A leaflet describing and illustrating the real protection for delicate electrical equipment. Littlefuse Laboratories, 1772 Wilson Avenue, Chicago, Ill.

IGNITION CONTROL. A preliminary instruction sheet for the Mercoid Type "TU" safety control and constant current Incandescent Ignition Control for Automatic Fuel Burners. The Mercoid Corporation, 4201 Belmont Avenue, Chicago, Ill.

VALVES. A leaflet describing an electric motor valve with automatic final shut-off. They are compact in design, dependable and quiet in operation. Minneapolis-Honeywell Regulator Co., Minneapolis, Minn.

TEMPERATURE. An 8 leaf circular entitled, "Chromium Plating Temperature," Temperature is a critical factor in chromium plating. To enable the plater to hold the temperature within the close limits essential for first quality work it is necessary to use an accurate thermometer. Foxboro Chromium Plating Thermometer has been made especially for this work. Foxboro Co., Foxboro, Mass.

FLOW METERS. These are direct mail pieces, one giving the different types of meters for all pressures up to 5000 pounds. The other is entitled "The 1930 Republic Flow Meter" and gives the list of men responsible for the design of the Republic Flow Meter. Republic Flow Meter Co., 2240 Diversey Parkway, Chicago, Ill.

SULPHITE & STEAM. During 1930 Republic Flow Meters Co. through the courtesy of various paper mill superintendents will present to the paper industry an interesting series of articles dealing with latest methods of increasing paper mill efficiency. The first of the series is entitled "Temperature Control in Cooking Sulphite Pulp," the second is entitled, "Reducing the Consumption of Process Steam in Paper Mills." Republic Flow Meters Co., 2240 Diversey Parkway, Chicago, Ill.

RECORDERS. A booklet describing and illustrating a chart, which gives the operator a complete record in triplicate of the performance of each truck, copy for the garage, for the district office and for the main office. It gives the exact mileage traveled, speed of every mile, exact time of each stop. There are many other interesting phases given in this booklet. Pittsburgh Taximeter Company, 530 Duquesne Way, Pittsburgh, Pa.

ROTOSCOPE. A booklet giving the slow motion study of rapidly moving parts from 100 to 40,000 r. p. m. and non-contact speed determination by the Ashdown Rotoscope. Livingstone & Southard Inc., Whitehall Bldg., 17 Battery Place, New York, N. Y.

WATER WORKS JOURNAL. The September 1930 issue contains the following articles: Short description of the Denver Municipal Water Works; New York City Use of Water Set Record in 1929, 318,842,100,000 Gallons Consumed in Year, 17,000,000,000 More Than in 1928; The Business Situation; Water Shortage in Draught Found Menace to Health. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

GAS SERVICE JOURNAL. The September 1930 issue of this journal contains the articles: Economics of Removing Locked Meters; Business Situation; L. J. Mueller Announces New Pressed Steel Gas Fired Furnace; Natural Gas and Prosperity; Economical Operation of Small Oil Wells. The October 1930 issue of the same journal contains articles on: Measurement At High Pressure with Diaphragm Type Meters; California—It's Yours; Promoting Natural Gas Sales; Why the Regulator Didn't Regulate; Just a Traveling Man; Pittsburgh Equitable Meter Company, 400 Lexington Avenue, Pittsburgh, Pa.

MEAURING INSTRUMENTS. This pamphlet is published by Lehman & Michels in Germany, but is written in English. It is published for the purpose of furnishing a succinct review of their products. It is divided into five parts: Indicated Power, Shaft H. P. Vibration Study, Material Testing, and Special Instruments. Lehman & Michels, Hamburg, Altona, Abt. I., Germany.

TUNING FORK. September 1930 issue of the Experimenter is the description of electrically-driven tuning forks by Horatio W. Lamson. The choice of tuning forks depend largely upon the requirements of the problem at hand. General Radio Company, Cambridge A., Mass.

APPARATUS, PARTS, ACCESSORIES. Bulletin 932, September 1930 describes the various kinds of apparatus used by radio service men, amateurs, experimenters, sound technicians, and custom set builders. General Radio Company, Cambridge A, Mass.

POLISHING MACHINE. A leaflet describing the Warner & Swasey Metallographic Polishing Machine, which was designed by a metallurgist and built by manufacturers of machine tools and instruments of precision. Its simplicity of design and rigidity ofconstruction make it ideal for metallurgists, consulting engineers, research chemists and technical school laboratories. Chemical Rubber Co., West 112th St. & Locust Ave., Cleveland, Ohio.

THE LABORATORY is a small booklet published for those interested in keeping informed on the latest developments of laboratory apparatus and technique. Technical Service Department, of Fisher Scientific Co., 711 Forbes St., Pittsburgh, Pa.

OSCILLOGRAPHS. Bulletin GEA-954A describes and illustrates the Cathode-Ray Oscillograph. This instrument has its principal use in the recording of extremely fast or transient phenomena. It can be used for the study of the effect of artificial lightning or by a slight modification, of natural lightning. General Electric Co., Schenectady, N. Y.

OSCILLOGRAPHS. Booklet GEA 1209-A describes: Six-element, general-purpose oscillographs, Two-element, portable oscillograph, continuous-viewing oscillograph, General Electric Co., Schenectady, N. Y.

SILENT AND ROLLER CHAIN. A new 124 page catalogue giving complete data on silent and roller chain, also engineering data of practical value to chain users in figuring chain drives. It also gives complete information and engineering data on sprockets used in conjunction with silent and roller chain drives and on chain attachments for special purposes. Union Chain & Mfg. Co., Sandusky, Ohio.

METERS. Circular 1787-A describes electrical equipment for railway signaling. This booklet gives the signal engineer and purchasing agent a condensed survey of the many Westinghouse items serving signal departments. Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

NICKEL. A 7 page leaflet entitled, "The Kocour Nickel Comparator." The Kocour Nickel Comparator is a practical method by which the nickel in solution is accurately, simply and directly measured. Price and description of this Nickel Comparator are given in the leaflet. This company also issued other leaflets entitled, "The LaMotte H-Ion Comparator Set," Standard Solutions," "Sulphates," and "Chlorides." Kocour Company, 4724 S. Turner Ave., Chicago, Ill.

CHROMIC ACID. This Kocour Chromic Acid Analytical Set is described and illustrated in a small pocket leaflet. It was developed to replace the hydrometer because of the latter's inaccuracy. Kocour Company, 4724 S. Turner Ave., Chicago, Ill.

BROWN INSTRUMENTS. This is a 24 leaf circular giving 24 cost cutters by using Brown Instruments. Brown Instrument Co., 4482 Wayne Ave., Philadelphia, Pa.

GRAPHIC INSTRUMENTS. Bulletin 727 shows how Esterline-Angus Graphic Instruments are used to record the test data on electric motors as they pass by the testing plant on a conveyor. Instead of using indicating instruments, pencils and log books, in the hands of human observers, the electrical data are automatically recorded by six Esterline-Angus graphic instruments. Three minutes are required for four complete tests of each motor. Esterline-Angus Co., Indianapolis, Ind.

INSTRUMENT INVESTMENT NEWS. Vol. III, No. 6, September 1930 issue of this circular is devoted to the Dissemination of Practical Information on the Measurement and Control of Manufacturing Operations. Consolidated Ashcroft Hancock Co. Inc., Bridgeport, Conn.

LABORATORY & POWER PLANT EQUIPMENT. Bulletin No. 15, September 1930, describes and illustrates the various scientific laboratory and power plant equipment. The Refinery Supply Company, Tulsa, Okla.

POLISHING MACHINE. This circular describes the Automatic Polishing Machine which was designed in the laboratory of the Bureau of Standards after careful, accurate analyses of existing operating methods and equipment. It automatically produces a plane surface with a high quality polish. The Chemical Rubber Company, West 112th St., Cleveland, Ohio.

DIAL GAGE. A circular describing and illustrating the dial thickness gage, model 390. It is a light convenient thickness gage used for measuring all kinds of flat material, such as felt, sheet metal, leather, etc. Federal Products Corp., Providence, R. I.

FURNACES. Direct mail piece No. 24, describes and illustrates how Hump hardening and Homo tempering furnaces are used for heat-treating the gears in caterpillar tractors. Leeds & Northrup Co., 4901 Stenton Avenue, Philadelphia, Pa.

TRANSFORMERS. Bulletin 716-Z describes the need for testing all potential transformers. Leeds & Northrup Co., 4901 Stenton Avenue, Philadelphia, Pa.

EXPERIMENTER. Vol. V, No. 5 of this publication describes the Frequency Stability of Piezo-Electric Monitors, and Synchronous Motor-Driven Clocks. The Experimenter is published monthly to furnish useful information about the radio and electrical laboratory apparatus manufactured by the General Radio Company, Cambridge A, Mass.

MICROPHOTOMETER. MF 29 illustrates how part of band spectrum of nitrogen recorded in less than 2 minutes with the type A microphotometer. The Improved "Moll" Recording Microphotometer is equipped with vacuum-thermocouple and micro-galvanometer by which the rapidity has become ten times that of the original type. Records are now made in less than 10 minutes. P. J. Kipp & Zonen, Delft, Holland.

SWITCHBOARD INSTRUMENTS. Catalog No. 48, July 1930, describes all Roller-Smith switchboard instruments and instrument transformers. Roller-Smith Company, 233 Broadway, New York, N. Y.

SPECTROPHOTOMETRY. This booklet dated August, 1930, is devoted to Biological applications of absorption spectrophotometry. The measurement of absorption spectra by means of spectrophotometry is now well established as a laboratory method. It has been used by chemists and has proved of great value in certain industries, such as dyeing. Adam Hilger, Ltd., 24 Rochester Pl., Camden Rd., London, N. W. 1, England.

RECORDING GAGES. Bulletin No. 168, is a 24-page booklet stressing the fact that Foxboro new gages have all steel . . . all welded movements and consequently last longer and give better service. The Foxboro Company, Neponset Ave., Foxboro, Mass.

TELEHEIGHT. A direct mail piece describing and illustrating Type C W Matthews Teleheight which quickly figures height of trees, poles, buildings, wire clearances, etc. It is very simple and accurate, anyone can work it. It is only five inches in length. Can be handily carried in vest pocket. W. N. Matthews Corp., 3713 Forest Park Blvd., St. Louis, Mo.

RESISTORS. Catalog No. 630 describes enameled slide resistors, imbedded in a highly insulating heat resistant, vitreous enamel. It is recognized as a standard and useful unit of electrical equipment. Hardwick, Hindle, Inc., 215Emmet St., Newark, N. J.

WATER WORKS JOURNAL. Vol.XXII, No. 10 of this publication contains the following articles: Use of Chlorine in Water Purification, Speed as a Business Aid, Law Suits, Excavations at Pompeii Reveal Old Water Pipes, City Water Cooling French Plane Motor, Montreal, North Carolina Water Supply, Iceland's Hot Springs are to be Piped into City Houses, New Water Supply System for Fort Lauderdale. Pittsburgh Equitable Meter Co., 400 Lexington Ave., Pittsburgh, Pa.

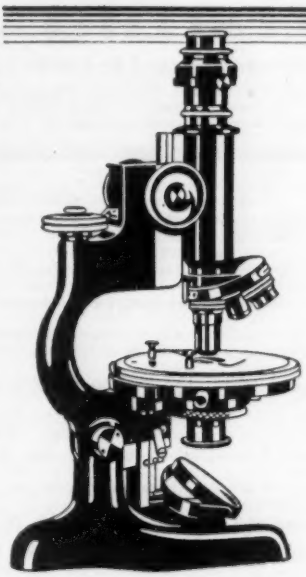
MEASURING INSTRUMENTS. Bulletin No. 1275 describes and illustrates the instrument known as "Jagabi," wnich is a Type C Hand Tachometer used for measuring instantaneous speed and for showing speed variations. They operate on the centrifugal principle and are independent of direction of rotation. They are recommended for indicating r.p.m. and surface speeds of all types of machinery in which the moving parts are readily accessible. James G. Biddle, 1211 Arch St., Philadelphia, Pa.

FREQUENCY METERS. Bulletin No. 1270 entitled "Frahm" possesses the following outstanding characteristics: no moving parts, accurate under all conditions, small power consumption, high initial and sustained accuracy, simple to install, where used and lastly Frahm frequency meters are exceedingly rugged. James G. Biddle, 1211 Arch St., Philadelphia, Pa.

MICRO-METALLOGRAPH. Catalog No. 1057 (2nd edition) describes the Leitz Micro-Metallograph as the standard for metallurgical examination. It is available in different equipments, viz: (1) essential outfit for control work; (2) medium outfit for advanced laboratory work and photography of finished material; (3) elaborate equipment for research investigations and photo-micrographic studies. This instrument is in daily use by foremost industrial, government and educational institutions. E. Leitz, Inc., 60 East 10th Street, New York.

TYCOS ROCHESTER. A publication published quarterly at the price of twenty-five cents a copy. Herewith are mentioned a few of the articles appearing in the October 1930 issue. Broadcasting Weather Maps by Radio, Rainfall and Its Measurement, American Universities Study Atmospheric Problems, Solving Skyland's Daylight Secrets, A Corner in Hurricanes, and The New Science of Atmospheric Comfort. Taylor Instrument Companies, Rochester, N. Y.

TECHNICAL INSTRUMENT BULLETIN. Vol. 2, No. 6 of this publication contains an article by Max Wolff, Ph.D., entitled "On Microscopic, Photographic and other Apparatus for Wood Research." Emil Busch Optical Co., Ltd., 37 Hatton Garden, London, E. C. 1.



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CURRENT LITERATURE REVIEW

Abstracts on instruments and devices for measurement, inspection and control

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GENERAL

Modern Developments in Control Instruments for Rubber Factories. L. Healy. Rubber-Age, June 25, 1920, pages 308-311.

Control instruments for dimensional measurements, humidity, plasticity, pressure, speed, temperature, time, weight and viscosity are briefly discussed. Paper presented before the Chicago Group Meeting, Rubber Division, American Chemical Society, Jan. 17, 1930.

Modern Developments in Instruments for the Rubber Industry. E. Stilson. Rubber Age, June 25, 1930, pages 311-314.

The following instruments are considered: recording gages, recording thermometers and cycle controllers. Paper presented before the Chicago Group Meeting, Rubber Division, American Chemical Society, June 25, 1930.

A New Engineering Laboratory. F. V. Larkin & S. S. Seyfert. Mechanical Engineering, Oct. 1930 pages 883-887.

A description of the James Ward Packard Laboratory of electrical and mechanical engineering at Lehigh University, and of the principles involved in its design and construction and operation.—G.N.

National Physical Laboratory—Annual Inspection of Apparatus. Instrument World, Aug. 1930, pages 89-90.

Brief summary of new developments and new work in progress at the English equivalent of our Bureau of Standards.—M. F. B.

Automatic Control with Photo-Electric Cells. E. H. Vedder. Electric Journal, July 1930, pages 407-10.

A number of applications of the photo-electric cell for automatic control which have been or are being made, using light sensitive devices for automatic control and which are regarded as representative of the types of problems encountered. Several illustrations are included.—W. H. B.

Hydraulic Power Committee Reports. Electrical West, May 15, 1930, pages 331-389.

Consists of reports of various subcommittees of the Hydraulic power committee, Engineering section, Pacific Coast Electrical Association. These include reports on "Automatic hydraulic regulatory and safety devices," and "Automatic frequency control in hydro-electric plants."— M.S.

LENGTH, AREA, VOLUME

The "Abameter" Quick-Measuring Tape (Der Abameter-Schnellmasstab). Zeitschrift fuer Feinmechanik und Praezision, July 31, 1930, pages 3-4.

The tape is a curved steel ribbon of about 6 ft. length easily bent in any shape and rigidly standing up in free length.—H. A.

SURVEYING

Measurement of Sags (Die Messung von Durchhaengen) R. Heimberger. Elektrotechnische Zeitschrift, Aug. 28, 1930, pages 1241-1242.

By providing the theodolite with a third orthogonal axis besides its own two axes an ordinary theodolite can be made to measure any sag of lines no matter whether the suspension points are on the same level or not or when the distance from ground can not be measured, even though the observer is not directly in front of the middle of the sag. The device is supplied by the Askania Werke, Berlin.—H. A.

A New Precision Distance-Surveying-Rod for Optical Measurement of Distances with Simultaneous Use of Existing Theodolites of Older Type (Eine neue Praezisions—Distanzlatte fuer optische Entfernungsmessungen bei gleichzeitiger Benutzung aelterer vorhandener Theodolite). Allgemein Vermessungsnachrichten, Aug. 27, 1930, pages 545-546.

Short description of some improvements.—H. A.

Standardization of Size of Pictures and Maps for Geodetic Drawings (Normung von Bildgrüssen und Papierformaten fuer geodaetische Zeichnungen, Plaene und Karten). Baumgart. Allgemeine Vermessungsnachrichten, Aug. 13, 1930, pages 513-519.

Suggestions for a standardization of dimension of sheets and of scales by the German committee on standards. Recommended are in particular squares for maps.—H. A.

The Development of the Zeiss Stereo-Planigraph From 1920 to 1930 (Die Entwicklung des Zeiss Stereoplanigraph von 1920 bis 1930). O. V. Gruber. Bildmessung und Luftbildwesen, Aug. 1930, pages 129-139.

The stereoplanigraph is photo-topographic double-projection instrument for the stereoscopic evaluation of pairs of photographs and serves for the making of maps from terrestrial and especially aero-surveys in any direction. The principle of the instrument is the reversal of the exposure and to reconstruct the position of the objective points from the intersection of the projective rays. How this is accomplished and what improvements have been added is described in detail.—H. A.

Test of the New Plume-Rod Distance Meter of C. Zeiss. Jena (Untersuchungen des nenen Lotstab—Entfernungamessers von C. Zeiss, Jena). W. Schneider. Zeitschrift fuer Vermessungswesen, Sept. 1, 1930, pages 591-606.

The purpose of this instrument is to permit carrying out a small-scale survey in rectangular coordinates quickly and exactly, especially without disturbing traffic. Abscissas and ordinates are measured optically, and the angles (one of 90°) determined with the double-penttagon prisms. The geodetic Institute in Stuggart examined such an instrument in all its parts and determined the accuracy of the results. With a personnel of one observer, two helpers and one recorder, the time required for the determination of one point was 1.6 minutes which easily permits determining 200 to 250 points per day. The obtained accuracy was found to be within the permissible error for districts with high traffic.—H. A.

New Collapsible Surveying Rod (Neue mehrteilige Nivellierlatte, verbesserte Einscherlatte) Hellwieg. Zeitschrift fuer Vermessungswesen, Aug. 15, 1930, pages 582-584.

Describes an improvement in surveying rods whereby the several parts are securely connected by a single screw by means of curved end pieces.—H. A.

GASES, AIR AND STEAM

Detection of Inflammable Gases. Edwin Lyon. Electrician, Sept. 5, 1930, pages 281-3.

Methods of detection and estimation of fire damp are outlined. The McLuckie and the Ringrose detectors are shown diagrammatically, also a section of CEAG combined oil-electric lamp for mine inspection and gas detection. A diagram also shows the height and shape of the gas cap for various percentages of methane for a lamp with a round wick and burning volatile spirit (gasoline). A check on any test can be made by securing a sample of the mixture for analysis. The oil-flame lamp is not suitable for detecting petrol vapors because the "cap" formed is not easily seen, particularly in the low percentage it is desired to detect. A bibliography of 16 references is appended. —W. H. B.

Hot-Sphere Anemometer Measures Air Velocities in Ventilating Ducts. C. J. Fechheimer & E. L. Harder, Electric Journal, Sept. 1930, pages 536-537.

The hot-sphere anemometer consists of a coil of wire wound into spherical form and covered by a small silver spherical shell, which is attached to a stem of convenient length. The wire in the coil has a high resistivity and negligible temperature coefficient. A copper and a constantan wire are soldered to the silver shell forming a thermocouple junction for measuring the surface temperature. The thermocouple and the heater leads are carried out through the stem. The external diameter of the sphere is about 0.33 inch. Thermal capacity is proportional to the volume of the sphere and the coefficient of heat dissipation varies with the surface area and depends upon some function of the velocity. The operation is based on the principle that the rate of cooling of a heated sphere placed in an air stream is proportional to the air velocity, regardless of the direction of the flow.—W. H. B.

ELECTRICITY

Over-Voltage Klydonograph (Der Ueberspannungs—Klydonograph). F. A. Foerster. Elektrizitaet im Bergbau, Aug. 19, 1930, pages 156-159.

Describes the apparatus for continuous supervision in a three-phase installation. A film in an enclosed box is moving under a point connected to the high-tension and showing any surge or higher than normal voltage by the characteristic Lichtenberg-figure after development of the film. The proper voltage for direct connection is about 2500 volts; for higher voltage condensers in series must be used, the instrument is connected to a part given the proper voltage.—H. A.

Iron-Clad Indicating Dynamometer (Eisengeschlossenes Zeiger-Dynamometer). Elektrotechnische Zeitschrift, Aug. 28, 1930, page 1243.

Instrument for alternating current with laminated iron core adapted to be used for measuring power factor, frequency, and, on aeroplanes, for the determination of location in foggy weather. —H. A.

The Concentric Wattmeter for Large Currents. C. H. Wright, Instrument World, Aug. 1930. pages 85-86.

Description of application of concentric system developed by Agnew in the U. S. and Moore in England.—M. F. B.

Stroboscopic Method of Testing Watthour Meters. Frederick Strattner & Edward J. Filemyr. U. G. I. Circle, Oct. 1930, pages 4-7.

Description of a new stroboscope developed in the meter laboratory of the Philadelphia Electric Company, which has proved its effectiveness in more accurate tests and lowered testing costs. One operator, using the new instrument, can test more meters than two men using old method. Possibility of adaptation to portable form, thus revolutionizing routine and effecting savings to public service industry.—M. F. B.

A Rapid Record Oscillograph. A. M. Curtis. Bell Laboratories Record, Aug. 1930, pages 580-585.

Statement of difficulties with previous instruments. One desideratum of new instrument was to be short waiting time for oscillograms. Outstanding feature of "Rapid Record" Oscillograph is that the picture, while its taking is controlled manually, is automatically developed, fixed, and passed slowly before the eye of the engineer within a few seconds after the exposure takes place. This oscillogram is ruled off automatically in abscissas of thousandths of seconds and ordinates of twentieths of inches, and, being on paper instead of sticky film, immediate measurements may be made. Description of construction features. The damping, instead of depending on a liquid of varying viscosity, is almost entirely electrical. The amplifier is so arranged that suitable input and output transformers can be switched into circuit and the number of tubes in last stages reduced to two when frequencies below 100 cycles per second are not required. The amplifier and oscillograph combination is 100 times more sensitive when operating on the band from 100 to 3000 cycles than when used for direct currents. Several examples illustrate the variety of studies which may be made with the new instrument.—M. F. B.

Increasing the Range of Voltmeters—Converting One Meter for Multi-Scale Operation. Radio Service, May, 1930, pages 3-4, 20.

Calculations of additional series resistances, etc.—M. F. B.

Kirchoff's Laws and Their Application to Radio Work. Technical Staff, Radio Service, April, 1930, pages 3-4.

The second of a series of articles on the scientific principles underlying the use of radio testing instruments and the solution of problems pertaining to flow of electric currents in a network of conductors.—M. F. B.

Voltmeters from Milliammeters—Modifying Milliammeters for Dual Purposes. Radio Service, April, 1930, pages 6-7.

Possibilities of such dual service. Special references are made to the Weston Model 301 and the Jewel Pattern 88 milliammeters of range 0 to 1 milliammeter.—M. F. B.

The Wheatstone Bridge in Service Work. James A. Dowie. Radio Service, Part I, April, 1930, pages 12, 13, 18; Part II, May 1930, pages 6, 7, 18.

Fundamentals. Emphasis on theory of potentiometer. Fundamental theory of alternating current work. Emphasis on the measurement of inductance, and of inductance and resistance —M. F. B.

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Bristol Company
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Taylor Instrument Companies

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Leeds & Northrup Co.
Rubicon Company

CABLE TESTERS
Leeds & Northrup Co.
Rawson Elec. Inst. Co.

CALORIMETERS—Gas
American Meter Co.
Burgess-Parr Co.

Peroxide, Oxygen Bomb
Burgess-Parr Co.
Gaertner Scientific Co

CAPACITANCE METERS
General Electric Co.
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

CARBON DIOXIDE METERS
American Meter Co.
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

CARBON MONOXIDE METERS
American Meter Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J

CATHETOMETERS
Gaertner Scientific Corp.

CEMENT TESTING INSTRUMENTS

CHRONOGRAPHS
Gaertner Scientific Corp.

CHRONOMETERS
Tagliabue Mfg. Co., C. J.

CLOCKS—Gauge Board
Brown Instrument Co.
Bristol Company
Foxboro Co.

CLOUD & POUR TEST APPARATUS
Tagliabue Mfg. Co., C. J.

COILS
Resistance, Inductance, Special.
General Radio Co.
Rubicon Company

COIL TESTING EQUIPMENTS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.

COLORIMETERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.

COMBUSTION CONTROL EQUIPMENT
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.

COMMUNICATION MEASURING INSTRUMENTS
General Radio Company

COMPASSES
Taylor Instrument Companies

COMPARATORS
B. C. Ames Co.
Federal Products Corp.
Gaertner Scientific Corp.
General Electric Co.

CONDENSER LEAKAGE RECORDERS
Esterline-Angus Company
Leeds & Northrup Co.

CONDENSERS—Electrical
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

CONDUCTIVITY METERS
Indicating, Recording, Controlling
Esterline-Angus Company
Leeds & Northrup Co.

CONCENTRATION RECORDERS
Esterline-Angus Company
Leeds & Northrup Co.

CONSTANT SPEED & FREQUENCY SETS
Leeds & Northrup Co.

CONTOUR MEASURING PROJECTOR
Bausch & Lomb Optical Co.

CONTROLS, AUTOMATIC
Condensation
Tagliabue Mfg. Co., C. J

Damper
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J

Demand Pressure
Foxboro Company

Feed Water
Brown Instrument Co.
Foxboro Co.

Filter Rate
Brown Instrument Co.
Foxboro Co.

Float

Flow
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Foxboro Co.

Gravity
Foxboro Co.
Tagliabue Mfg. Co., C. J.

Humidity
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Humidity & Temperature
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Liquid Level
Automatic Temperature Control Co., Inc.
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J

Motor

Pressure & Vacuum
Automatic Temperature Control Co., Inc.
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Minneapolis-Honeywell Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

A Vacuum-Tube Voltage Regulator for Alternators. L. C. Verman & L. A. Richards. Review of Scientific Instruments, Oct. 1930, pages 581-591.

A vacuum tube voltage regulator for ac power units is described, with two novel features. First, saturation current from the filament of a thermionic tube is used as the control element; and second, a feed-back stabilization system is employed which makes it possible to obtain stable regulated voltage conditions with high sensitivity. It gives voltage regulation of 1.5% at full load unity power factor as compared to 45% with fixed excitation. The regulator also functions as an overload circuit breaker. Results of tests conducted under steady, transient, and short circuit conditions are given. Finally some further improvements are suggested.

An Electrical Impulse Rate Indicator and Recorder. W. W. Macalpine. Review of Scientific Instruments, Sept. 1930, pages 523-526.

A circuit is described which is operated by impulses and in which the reading of a meter is a function of the rate of the impulses. In the present instance the impulses operate a Weston Model 30 Galvanometer Relay whose contacts discharge a condenser. The condenser is charged up again through a resistance after each impulse, and a microammeter reads the average voltage across the resistance. A smoothing circuit is used between the microammeter and the resistance. Variations of the device may be used according to the nature of the impulses. A Leeds and Northrup Recording Potentiometer may be attached to the device to obtain a continuous record of the rate. In another form, the average voltage may operate on the grid of a tube, the plate current of which operates a more rugged indicating meter than the microammeter. This also simplifies the filter circuit. Means for calibrating the device are discussed.

A Quantitative Experimental Method of Mapping Equipotential Lines and its Application to Electric Precipitator Problems. A. W. Simon & L. C. Kron. Review of Scientific Instruments, Sept. 1930, pages 527-536.

A quantitative method of mapping a series of equipotential lines corresponding to definite fractions of the total voltage drop between electrodes is described. The accuracy of the method is tested by mapping several known fields, such as the field between concentric cylinders and that between parallel cylinders. The application of the method to electrostatic problems, in particular to the study of electric precipitiation problems, is indicated.

Magnetic Circuit Units (Les unites du circuit magnetique). A. E. Kennelly. Revue Generale de l'Electricite, June 14, 1930, pages 923-924.

Includes discussion by Paul Janet. Bibliography of 30 references. Translation of paper presented before American Institute of Electrical Engineers, Jan. 27-31, 1930, and published in **Transactions of the American Institute of Electrical Engineers,** April 1930, pages 486-494. Presents a brief history of the development of magnetic—circuit units, especially during the last 40 years, so as to help visualize the present status of these units; indicates the reasons existing for changing that status and submits a few suggestions in that direction to start discussion in the American Institute of Electrical Engineers.—M. S.

Modification of the Kohlrausch Bridge for Measuring Alternating Current Resistances (Modification du pont de Kohlrausch pour la mesure des resistances en courant alternatif). E. Denina Revue Generale de L'Electricite, May 10, 1930, pages 737-738.

Abstract from **Annali di Chemica Applicata,** Vol. 18, no. 12, pages 529-540. Describes arrangements used in measurements concerning electrolytes.—M. S.

Bridge for Measuring Dielectric Losses of High-Tension Bushing Insulators and Condensers (Pont pour la mesure des pertes dielectriques dans les isolateurs de traversee et les condensateurs pour haute tension). Enzo Pugno-Vanoni, Revue Generale de l'Electricite, April 26, 1930, pages 657-658.

Abstract from **L'Elettrotecnica,** Jan. 15, 1930, pages 37-41. Mathematical treatment of the design of the bridge, and a description of an actual installation. No standard capacity is required. —M. S.

Insulating Materials and Their Testing (Isoliermittel und deren Pruefung). K. Konstantinowsky. Elektrotechnik und Maschinenbau, March 23, 1930, pages 262-269.

Report of the fifth convention of the Conference Internationale des Grands Reseaux a Houte Tension, Paris, 1929. Deals with oils cables, testing plants, testing of insulating materials, and insulation of machines.—M. S.

Trailing—Cable Tester. Electrical Review, July 4, 1930, pages 40-41.

Describes the "Allscott" cable tester, developed by James Scott & Co., Dunfermline, to show when a trailing cable is unsafe, and where the unsafe portion actually is.—M. S.

Precise Measurements with the Larsen Alterating-Current Potentiometer (Les mesures de precision avec le potentiometre de Larsen a courant alternatif). L'Industrie Electrique, June 10, 1930, pages 245-246.

The Larsen potentiometer, which is very simple, has lacked for a long time a suitable oscillator, in order to make it more generally useful. Describes a modified instrument, whereby the error of mutual inductance is reduced almost to zero. Outlines briefly the theory of the instrument and several applications.—M. S.

Two-Wattmeter Method and the Power Factor of Induction Motors (La methode des deux wattmetres et le facteur de puissance des moteurs d'induction). Geo. de Ryckere. L'Industrie Electrique, May 25, 1930, pages 232-234.

From **Bulletin de l'Association des Ingenieurs de Montefiore,** Dec. 1929. The two-wattmeter method does not give exact measurements of the mean true power, but gives only approximations. Recommends the use of a double wattmeter with a single needle, which gives directly in a single reading the result of the algebraic sum of the readings of the two separate wattmeters.—M. S.

Liquid Dielectries. D. H. Black. Electrical Review, July 25, 1930 pages 135-136.

Describes method of measuring the specific a. c. resistances of insulating liquids, in which the effects of external leakages are claimed to be entirely eliminated. Consists in using as a testing vessel for the liquids some form of variable condenser in which all the moving parts not symmetrically placed with respect to the external circuit can be completely immersed in the liquid. Conductance measurements are made by means of the Wheatstone bridge method.—M. S.

Train-Testing Equipment. Electrical Review, July 25, 1930, pages 156-157.

Gives some particulars of the electrical equipment for indicating, recording, and integrating the current, power and voltage, designed by Everett, Edgcumbe & Co. Ltd., for a recently built dyanometer car of the India State Railways. Pays particular attention to the recording mechanism, as the speeds required are very high.—M. S.

Pyrometer
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Rate-Volume
American Meter Co.
Foxboro Co.
Refrigeration
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Special
Automatic Temperature Control Co., Inc.
Rubicon Company
Tachometer
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Temperature-Time
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.
Thermometer
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Thermostat
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Minneapolis-Honeywell Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Thickness
Esterline-Angus Company
H. Z. Schniewind
Time
Automatic Temperature Control Co., Inc.
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Stromberg Electric Co.
Tagliabue Mfg. Co., C. J
Unit Heater
Minneapolis-Honeywell Co.
Vacuum
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Meriam Co.
Valve—Motor Operated
Automatic Temperature Control Co., Inc.
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Minneapolis-Honeywell Co.
Taylor Instrument Companies
Water Level
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Tagliabue Mfg. Co., C. J.

COORINATOGRAPHS
COUNTERS—Revolution
Bristol Company
Brown Instrument Co.
Lehmann & Michels
H. Z. Schniewind
Stroke
Bristol Company
Esterline-Angus Company
Lehmann & Michels

COUPLING TRANSFORMERS
General Radio Company

CURRENT RECORDERS
Bristol Company
Esterline-Angus Company
Leeds & Northrup Co.

CURRENT REGULATORS
Westinghouse Elec. & Mfg. Co

CYCLE COUNTERS
General Radio Co.

CYLINDERS-GRADUATED
Tagliabue Mfg. Co., C. J.

DECELEROMETER

DEFORMETER (Beggs)
Southwark Fdy. & Mach. Co.

DEMAND METERS
Gas
American Meter Co.
Foxboro Company
Electric
General Electric Co.
Westinghouse Elec. & Mfg. Co.

DENSITOMETERS
Akatos, Inc.

DENSOMETERS
H. Z. Schniewind

DIVIDING HEAD
Optical
Bausch & Lomb Optical Co.

DIVIDING MACHINES
Gaertner Scientific Corp.

DRAFT GAGES—see Gages

DYNAMIC BALANCING EQUIPMENT
Commercial Engg. Labs

EARTH CURRENT METERS
Rawson Elec. Inst. Co.

ELECTRIC TELEMETER
Southwark Fdry. & Mach. Co.

ELECTRIC WAVE FILTER SECTIONS
General Radio Company

EMPLOYEES' "IN AND OUT" TIME RECORDERS
Stromberg Electric Co.

ENGINE INDICATORS
Commercial Engg. Labs.
Lehmann & Michels

EXTENSOMETER
H. Z. Schniewind
Southwark Fdry. Mach. Co.

FATIGUE TESTERS
H. Z. Schniewind

FAULT FINDERS
General Radio Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

FLASH & BURNING POINT TESTERS
Akatos, Inc.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Co.

FLOW METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

FLUXMETERS
Leeds & Northrup Co.
Rawson Electrical Instr. Co.

FOLDING TESTER
H. Z. Schniewind

FREQUENCY METERS
Indicating
General Electric Co.
Jewell Electrical Instrument Co
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
Weston Elec. Inst. Corp.
Controlling
Leeds & Northrup Co.
Recording
Bristol Company
Esterline-Angus Company
Leeds & Northrup Co.
Standards
General Radio Co.

FUEL ANALYSIS APPARATUS
Burgess-Parr Co.

FUEL FLOW INDICATOR
Commercial Engg. Labs.

FURNACE CONTROLS
Automatic Temperature Control Co., Inc.

GAGE RODS
Tagliabue Mfg. Co., C. J.

GAGES
Absolute Pressure
Bristol Company
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Amplifying
B. C. Ames Co.
Federal Products Corp.
Comparator
B. C. Ames Co.
Federal Products Corp.
Cylinder
B. C. Ames Co.
Federal Products Corp.
Depth
B. C. Ames Co.
Federal Products Corp.
Dial
B. C. Ames Co.
Federal Products Corp.
H. Z. Schniewind
Differential Pressure
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Meriam Co.
Tagliabue Mfg. Co., C. J
Draft
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Drill
Bausch & Lomb Optical Co
Grinding
Federal Products Corp.
Liquid Level
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Loss of Head
Brown Instrument Co.
Foxboro Co.
Meriam Co.
Pitch Diameter
Federal Products Corp.
Pocket
H. Z. Schniewind

Copper-Oxide Rectifiers. C. W. Oatley. Electrical Review, July 18, 1930, pages 90-92.
Discusses their use in the construction of alternating-current measuring instruments, and describes some experiments on the characteristics of rectifier meters.—M. S.

Faults in Testing Batteries. D. K. McClury. Electrical Review, June 13, 1930, pages 1102-1103.
Considers the effect of battery earth leaks on the accuracy of the so-called direct deflection method of testing high resistances, e.g. the insulation resistance of a length of cable. Stresses the necessity of well-insulated guard plates.—M. S.

Low Power-Factor Measurements. E. H. Rayner, W. G. Standring, R. Davis, & G. W. Bowdler. Electrical Review, April 25, 1930 page 799.
Extracts from a paper read before the Meter and Instrument Section of the Institution of Electrical Engineers. Investigation of the power loss in high-voltage cables. Describes the air condenser and resistor developed for use in making measurements.—M. S.

Meter Committee Reports. Electrical West, May 15, 1930, pages 390-402.
Consists of reports of subcommittees of the Meter committee, Engineering section, Pacific Coast Electrical Association. These include "Application of 5-ampere meters to modern lighting installations," dealing with tests to determine to what extent these meters register slow; "Current transformer meters," giving the results of tests comparing the performance of the new 2.5-amp. meter and the 5-amp. meter for use with current transformers; "Courses for metermen;" "Investigations and tests on various forms of relays;" "New developments in meters," consisting of statements from the leading manufacturers; "Circuit tester for watthour meters," which, fundamentally, is a low resistance telephone receiver in series with a low-voltage battery with the two end terminals arranged to be connected to the circuit in question; and "Practical magnet testing device," which makes use of a relay and a cycle counter for determing relative strength of permanent magnets. —M. S.

Line Surge Investigations. S. W. Melsom, A. N. Arman, & W. Bibby. Electrical Review, April 18, 1930, pages 754-755.
Extracts from a paper read before the Institution of Electrical Engineers. Includes discussion. Deals with klydonograph measurements of surge voltages made under actual working conditions on 33-kva overhead, underground-cable, and composite transmission lines.—M. S.

Phase-Rotation Indicator. Electrical Review, March 28, 1930, page 586.
Brief description of instrument manufactured by Ferranti, Ltd. Consists of a miniature 3-phase induction motor, the disk of which rotates in a direction corresponding to the phase rotation of the circuit to which it is connected. Pressure range is 40-500 v. and frequency range, 20-100 cycles. —M. S.

Watthour Meter Testing. H. F. Leeper. Electric Light & Power, May 1930, pages 42-45.
Describes methods of testing as conducted by the Ohio Power Co. Methods are divided into following classes: 1—Laboratory testing; all meters. 2—Field testing; (a) single phase meters; (b) three phase meters; (c) direct current meters.—M. S.

Coin-in-the-Slot Meter in Connection with Rebate-Counter (Muenzzaehler mit Mehrverbrandes—Rabatt—Tarifwerk). H. Schultze. Elecktrotechnische Zeitschrift, Aug. 28, 1930, pages 1231-1232.
Describes an arrangement which should stimulate greater energy consumption on the part of the consumer by offering special monthly rebates for higher consumption than stipulated.—H. A.

Cathode-Ray Oscillograph Without Glass Parts. Electrical World, Aug. 16, 1930, page 303.
A novel cathode-ray tube has glass entirely eliminated. A Lenard window allows free passage of the recording beam to a photographic plate or film, located outside the vacuum. This tube is suitable for potentials up to 80 kv and currents up to 0.2 millamps. and can be left in operation all day without attention. The emission window consists of a Cellon sheet, 0.016 mm. thick, which withstands external pressure due to a reinforcing supporting structure of a fine mesh metal screen and a grill work of small edgewise steel bars. Sixty percent of the electrons are claimed to pass such a window with undiminished speed. Very clean cut records are procured and the new oscillograph is much smaller and more portable than the former glass type.—W. H. B.

Cadmium Battery Test Shows Actual Condition of Lead-Acid Cells. C. V. Hetherington. Electric Journal, Aug. 1930, pages 483-484.
The function of the cadmium tester is to check the condition and capacity of each set of plates and determine which is defective. When an electrode of cadmium and both the positive and the negative groups of plates are employed the algebraic sum of these respective potentials will be equal to the internal e. m. f. of the cell. The tester consists of: a cadmium stick, a sensitive voltmeter, and 2 pointed "spike" with wooden holders, used to make the terminal connections. Cadmium is used as intermediate electrode. It is insulated by a perforated rubber sleeve. For test, place on discharge a previously charged battery and take the cadmium-to-positive and the cadmium-to-negative potential readings of each cell at hourly intervals. A meter has been developed with satisfactory sensitivity and sufficient ruggedness. It has a scale with a maximum deflection over the working range.—W. H. B.

POWER, WORK AND OUTPUT

Alternations and Tests of the "Farnboro" Engine Indicator. John H. Collins, Jr. Technical Note No. 348, National Advisory Committee for Aeronautics, 14 pages.
The "Farnboro" electric indicator was tested as received from the manufacturers, and modifications made to the instrument to improve its operation. The original design of disk valve was altered so as to reduce the mass, travel, and seat area. Changes were made to the recording mechanism, which included a new method of locating the top center position on the record. The effect of friction on the motion of the pointer while taking motoring and power cards was eliminated by providing a means of putting pressure lines on the record. The modified indicator gives a complete record of the average cyclic variation in pressure per crank degree for any set of engine operating conditions which can be held constant for the period of time required to build up the composite card. The value of the record for accurate quantitative measurement is still questioned, although the maximum indicted pressure recorded on the motoring and power card checks the readings of the balanced diaphragm type of maximum cylinder pressure indicator.

The Engine Indicator as a Guide to Performance. H. A. Gehres. Cooper-Bessemer Monthly. Aug. 1930, pages 3-5.
Eighth and concluding installment of a series of articles on this subject. Test data from indicator cards. Methods of obtaining mean indicated H. P., mechanical efficiency, compressor efficiency, etc.—M. F. B.

Pressure
American Meter Co.
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Pressure-Temperature
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Cos.

Pressure & Vacuum
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Meriam Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

Profile
Bausch & Lomb Optical Co.

Rain
Taylor Instrument Companies

Recording

Distance
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Claud S. Gordon Co.

Strain
Southwark Fdry. & Mach. Co.

Thickness
B. C. Ames Co.
Esterline-Angus Company
H. Z. Schniewind

Volume
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

Water Level for Boilers
Bristol Company
Brown Instrument Co.
Foxboro Co.

Wind
Brown Instrument Co.
Taylor Instrument Companies

GALVANOMETERS
Brown Instrument Co.
Charles Engelhard, Inc.
General Radio Co.
Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

GAS ANALYTICAL METERS

Chemical
American Meter Co.
Tagliabue Mfg. Co., C. J.

Electrical
Brown Instrument Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.

GAS LEAK INDICATORS
Taylor Instrument Companies

GAS-METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

GASOMETERS
American Meter Co

GEOPHYSICAL INSTRUMENTS
Akatos, Inc.

GOVERNORS

Laboratory Dry & Wet Gas
American Meter Co.

Pressure
Bristol Company
Brown Instrument Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

Pump
Tagliabue Mfg. Co., C. J.

GLASS STRAIN TESTERS
Akatos, Inc.

GREASE TESTING APPARATUS
Tagliabue Mfg. Co., C. J

GROUND DETECTORS
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.
Weston Electric Inst. Corp.

GROUND-OHMER
Leeds & Northrup Co.
Herman H. Sticht & Company

GYPSUM TESTING INSTRUMENTS
H. Z. Schniewind

HARDNESS TESTERS
Akatos, Inc.
Claud S. Gordon Co.
H. Z. Schniewind
Wilson-Maculen Company, Inc.

HARMONIC ANALYZERS
Leeds & Northrup Co.

HELIOSTATS
Gaertner Scientific Corp.

HIGH FREQUENCY APPARATUS

HIGH VOLTAGE

Indicators

Measuring Devices
General Electric Co.
Westinghouse Elec. & Mfg. Co

Testing Devices
General Electric Co.
Westinghouse Elec. & Mfg. Co.

HUMIDITY CONTROLLERS
Bristol Company
Charles Engelhard, Inc.
Foxboro Co.

HUMIDITY RECORDERS

Wet & Dry Bulb Thermometers
Bristol Company
Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

HYDROGEN ION METERS

Indicating
Leeds & Northrup Co.
Rubicon Company

Controlling, Recording
Leeds & Northrup Co.

HYDROMETERS
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

HYGROMETERS
Brown Instrument Co.
Foxboro Co.
H. Z. Schniewind
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

IMPACT HARDNESS TESTER
H. Z. Schniewind

IMPACT TESTING MACHINES
Akatos, Inc.
H. Z. Schniewind

Alternating

INDICATORS—See Gauges

INDUCTANCES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

INSTRUMENT BOOKS
Instruments Publishing Co.

INSTRUMENT CALIBRATION AND REPAIRS
Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Rubicon Company

INSTRUMENT TRANSFORMERS
General Electric Co.
Jewll Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.

INSULATION TESTING EQUIPMENT
General Electric Co.
Leeds & Northrup Co.
Rubicon Company
Westinghouse Elec. & Mfg. Co.

INTEGRAPHS & INTEGRATORS
Leeds & Northrup Co.

INTERFEROMETERS
Gaertner Scientific Corp.

JOB TIMING RECORDERS
Stromberg Electric Co.

KEYS AND SWITCHES
General Radio Co.
Leeds & Northrup Co.
Rubicon Company

KILNBOY
Foxboro Co.

KILOVOLT AMPRERE METERS
Esterline-Angus Company

KLYDONOGRAPHS
Westinghouse Elec. & Mfg. Co.

LACTOMETERS
Tagliabue Mfg. Co., C. J.

LENGTH MEASURING MACHINES
Gaertner Scientific Corp.
H. Z. Schniewind

LEVELS

Centering
Bausch & Lomb Optical Co.

Engineer's, Wye, Precision

Prism
Taylor Instrument Companies

LIME TESTING INSTRUMENTS

LOCOMOTIVE INDICATORS
Lehmann & Michels

LUSTER METERS
Akatos, Inc.

MAGNETOMETERS
Rubicon Company

MANOMETERS
American Paulin System, Inc.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

MASTER CLOCKS
Gaertner Scientfiic Corp.
Stromberg Electric Co.

MEASUREMENT BOOKS
Instrument Publishing Co.

MEGOHMMETERS
Leeds & Northrup Co.
Rubicon Company
Herman H. Sticht and Company

MEGOHM VOLTMETERS
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp

MELTING POINT APPARATUS
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.

METER PROVERS, Gas
American Meter Co.

METER TESTERS, Gas
American Meter Co.

MICROMETERS
Gaertner Scientific Corp.
H. Z. Schniewind

MICROAMMETERS
General Electric Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co
Weston Electrical Inst. Corp.
Wilson-Maculen Company, Inc.

MICROFARADMETERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.

MICRO PYROMETERS
Akatos, Inc.

TEMPERATURE AND MOISTURE

Thermal Control Equipment of the High-Pressure Steam Installation in the Simmering Power-Plant of the Vienna Municipal Electricity Works (Die waermetechnischen Ueberwachungsanlagen der Hochdruckdampfanlage im Kraftwerk Simmering der Wiener Stadtischen Elektriqitatswerke). Rudolf Mokesch. Elektrotechnik und Maschinenbau, vol. 48, pages 364-369.

Describes measuring instruments and control apparatus in the boiler-plant and turbine room. —M. S.

New Total Radiation Optical Pyrometers (Nouveaux pyrometres optiques a radiation to tale). S. Held. Revue Generale de l'Electricite, June 21, 1930, pages 979-991.

Described two types designed and built by Etablissements Chauvin et Arnoux. A chair of thermo-electric couples is used in the first. The second, which is called an "optico-magnetic" pyrometer, makes use of the variation in magnetic susceptibility with temperature, of certain nickel alloys. Two elements composed of this alloy are placed in a magnetic field, one being exposed to the heat rays and the other forming the opposing couple. Discusses the theory of its operation. —M. S.

Quartz Rod Thermostat Accurate and Inexpensive. Electrical World, July 26, 1930, page 193.

Accuracy to a high degree, together with low cost is claimed for a quartz rod thermostat, for controlling the temperature of soft metal melting pots, which is manufactured by the General Electric Co. The thermostat consists of an inclosed switch with a nickel chrome iron tube extending from its base and surrounding a steel piston and quartz rod. The temperature range is 450-950°F, and will control temperatures to within 14°F. of its setting.—W. H. B

Automatic Regulation of Electric Furnaces in the Foundry (La regulation antomatique des fours electriques de fonderie). A. Levasseur. Revue Generale de l'Electricite, April 26, 1930, pages 665-670.

Part of a lecture on construction and use of electric furnaces, delivered before the Association Technique de Fonderie, May 4, 1929, and published in full in Bulletin de l'Association Technique de Fonderie, vol. 3, Dec. 1929, pages 478-493. Outlines the principle of pyrometric regulation, and describes pyrogalvanometric and potentiometric regulators. Discusses the different equations for automatic regulation, and describes the Brown, Boveri hydraulic pitson regulator, and the Secomet-Vastel electric motor regulator.—M. S.

Measurement of High Temperatures. Basil Barham. Electrical Review, April 18, 1930, page 720.

Note on the use of thermo-couples for metal treating furnaces.—M. S.

On the Influence of Atmosphere, Temperature and Material of Protection Tubes on the Stability of Platinum Thermocouples. (Ueber den Einfluss von Gluehatmosphare, Gluehtermperatur und Schutzvohrsbaustoffen auf die Bestaendigkeit von Thermoelementen. F. Staeblein & J. Hinuber. Archiv fuer Eisenhuettenwesen, June 1930, pages 781-785; Stahl und Eisen, July 31, 1930, pages 1089-1090.

The platinum wire of platinum thermocouples should always be protected by a protective tubing for practical use. Primary tests proved that the influence of various gases can be neglected for temperatures up to 900°C. The main tests were carried up to 1000°C; the influence of gases was found to be decreasing in the following order: hydrogen, carbon monoxide carbon dioxide, air. The influence of protective tubes was also examined. Reducing gases in the presence of metals, metal oxides and silicates destroy the noble metals. Tests prove that the destructive materials have to be present first as vapors. Gases themselves have no essential influence on the destruction of thermocouple wires. The picking up of foreign material was proved by an increase of electric resistance and weight. The change of the mechanical properties of used thermocouple wires was studied by bending tests. Platinum wire used with protective tubing in hydrogen atmosphere stood 45 bendings. The corresponding figures for platinum-rhodium wire are 35 and 55 respectively. In using thermocouples in eliminating gas the platinum-rhodium wire is quicker covered with soot.—G. N.

HEAT UNITS AND COMBUSTION

An International Heat-Unit (Eine internationale Warmeeinheit). M. Jacob. Zeitschrift Verein deutscher Ingenieure, June 21, 1930, page 880.

It is recommended to accept, as international standard of a heat-unit the unit proposed by the London International Steam Tables Conference, namely that heat-unit which is equivalent to 1/860 international Kilowatthours and to give it the name "International Kilo-Calorie." This value of 1/860 differs by not more than 0.05% from the Kilo-Calorie used at present in different countries, and eliminates the difficulty of determining whether the average calories or true calorie should be used as basis for mechanical heat-equivalent.—H. A.

Instruments, Automatic Control and Plant Records. Electrical West, May 15, 1930, pages 443-446.

Report of a subcommittee of the Prime movers committee, Engineering section, Pacific Coast Electrical Association. Contains descriptive data and operating experiences with certain types of automatic control equipment in use on the Pacific Coast as follows: (1) Automatic combustion control equipment, (2) System of remote control of gas pressure regulators, and (3) Feedwater regulation.—M. S.

The Determination of the Calorific Value of Coke Oven Gas in the Calorimeter by Junker. (Die Heizwertbestimmung von Koksofengas mit dem Junker'schen Heizwertmesser). H. Grewe. Archiv fur Eisenhuttenwesen, Aug. 1930, pages 75-85; Stahl und Eisen, Sept. 4, 1930, pages 1269-1270.

Report 77 of the Chemical Committee of the Verein deutscher Eisenhuttenleute. The general principles for the determination of the calorific value of gases are outlined. These are: (1) gas combustion, air and waste gas must have the same temperature; (2) gas, combustion air and waste gas must be completely saturated with water vapor; (3) the vaporization heat of the contraction water has to be substracted from the upper calorific value. Junker's Calorimeter can be easily equipped with a device for moistening the combustion air, thus fulfilling the above outlined requirements. New devices for moistening the air and cooling the waste gases have been designed and described. A new equipment has, furthermore, been constructed for a reliable checking of the gas quantity to be burned.—G. N.

MICROSCOPES
Bri nell
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Claud S. Gordon Co.
H. Z. Schniewind
Spencer Lens Co.
Metallographic
Akatos, Inc.
Bausch & Lomb Optical Co.
Claud S. Gordon Co.
Spencer Lens Co.
Petrographical
Akatos, Inc.
Bausch & Lomb Optical Co.
Spencer Lens Co.
Toolmakers'
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Spencer Lens Co.

MICROTOMES
Bausch & Lomb Optical Co.
Spencer Lens Co.

MILLIAMMETERS
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General Electric Co.
General Radio Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MILLIVOLTMETERS
Bristol Company
Charles Engelhard, Inc.
General Electric Co.
Jewell Electrical Instrument Co.
Rawson Electrical Instrument Co.
Taylor Instrument Companies
Weston Electrical Inst. Corp.
Wilson-Maeulen Company, Inc.

MOTOR RADIATOR VALVES
Minneapolis-Honeywell Co.

MOTION RECORDERS
Mechanical
Bristol Company
Foxboro Co.
Lehmann & Michels

MULTIMETERS
Rawson Electrical Instrument Co.

MULTIPLIERS
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Weston Electrical Inst. Corp.

NEON FILLED TUBES

NEPHELOMETERS
Akatos, Inc.

OHM METERS
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co
Rubicon Company
Herman H. Sticht and Company
Weston Electrical Inst. Corp.

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OIL TESTING APPARATUS
General Electric Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies

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Brown Instrument Co.
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

ORIFICE METERS
American Meter Co.
Brown Instrument Co.
Foxboro Co.
Meriam Co.

ORSAT APPARATUS

OSCILLOGRAPHS
General Electric Co.
General Radio Co.
Westinghouse Elec. & Mfg. Co.

OXYGEN RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.

PANTOGRAPHS
Gaertner Scientific Corp.

PERFORMANCE METER

PERMEAMETERS
Leeds & Northrup Co.
Rubicon Company

PAPER TESTING INSTRUMENTS
H. Z. Schniewind
Spencer Lens Co.

PERISCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.

PHASE INDICATOR
Westinghouse Elec. & Mfg. Co.

PHASE SEQUENCE INDICATOR
Herman H. Sticht Co.

PHOTOELECTRIC COLOR ANALYZERS
General Electric Co.

PHOTOELECTRIC COLOR COMPARATOR
General Electric Co.

PHOTO-ELECTRIC TUBES
General Electric Co.

PHOTOMETERS
Akatos, Inc.
American Meter Co.
Gaertner Scientific Corp.
Bausch & Lomb Optical Co.
Leeds & Northrup Co.

PHYSICAL TESTING MACHINES
Claud S. Gordon Co.
Lehmann & Michels
H. Z. Schniewind
Southwark Fdry. & Mach. Co.

PITOT TUBE METER
Brown Instrument Co.
Foxboro Co.

PLANIMETERS
Automatic Flow Record
Brown Instrument Co.
Linear
Brown Instrument Co.
Lehmann & Michels
Radial
American Meter Co.
Bristol Company
Foxboro Co.
Square Root
Foxboro Co.

POLARISCOPES
Akatos, Inc.
Gaertner Scientific Corp.

POSITION RECORDERS
Bristol Company
Esterline-Angus Company
Foxboro Co.

POTENTIAL DETECTORS
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.

POTENTIOMETERS—Indicating
Brown Instrument Co.
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Rubicon Company
Recording & Controlling
General Electric Co.
Claud S. Gordon Co.
Leeds & Northrup Co.

POWER FACTOR METERS
Esterline-Angus Company
General Electric Co.
Jewell Electrical Instrument Co.
Westinghouse Elec. & Mfg. Co.
Weston Eelectrical Inst. Corp.

POWER FACTOR REGULATORS
Rubicon Company
Westinghouse Elec. & Mfg. Co.

PRESSURE RECORDERS
Esterline-Angus Company
Foxboro Co.

PRICESS TIMING AND SIGNALING INSTRUMENTS
Stromberg Electric Co.

PROGRAM INSTRUMENTS
Automatic Temperature Control Co., Inc.
Stromberg Electric Co.

PROJECTION LANTERNS
Bausch & Lomb Optical Co.
Spencer Lens Co.

PROTRACTOR
Optical
Bausch & Lomb Optical Co.

PSYCHROMETER
Recording
Bristol Company
Foxboro Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Sling
Taylor Instrument Companies

PYROMETERS
Optical
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Radiation
Indicating
Brown Instrument Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Recording
Brown Instrument Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Thermo-electric
Immersion
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Indicating
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Westinghouse Elec. & Mfg. Co.
Wilson-Maeulen Company, Inc.
Recording and Controlling
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Taylor Instrument Companies
Wilson-Maeulen Company, Inc.
Surface Contact
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
Taylor Instrument Companies

RADIO FREQUENCY OSCILLATORS
General Radio Company

RADIO SET ANALYZERS
General Radio Company
Jewell Electrical Instrument Co.
Weston Electrical Inst. Corp.

RADIO TUBE CHECKERS
General Radio Company
Jewell Electrical Instrument Co
Weston Electrical Inst. Corp.

INSPECTION

The Preparation of Fiber Test Sheets. M. Shaw, G. Bicking & L. Snyder. Bureau of Standards, Journal of Research, July 1930, pages 105-114.

The need in the paper-marking research at the Bureau for a laboratory test that is analogous to paper-mill processes has led to the construction of a suction sheet machine and the development of a method of preparing fiber sheets. The test procedure relates to the forming of the sheet on the mold and the subsequent operations of couching, pressing, and drying. A complete description of the equipment and technic employed is given. Test data on the finished papers show that the fibers are uniformly distributed in sheets made by the method described, and that the different sheets of a series made from a given sample of stock are in close agreement, and can be duplicated as desired. The personal equation is reduced to a minimum and comparable results are obtained by different operators. The size of the finished sheets is adequate to supply specimens for each kind of test ordinarily made to evaluate the quality of paper. The results obtained warrant the view that the method is practical and is useful for mill control or paper-making research.

Magnetic Induction and Oscillograph Apparatus Developed for Steel Tests. Automotive Industries, April 5, 1930, pages 550-551, 559.

A magnetic induction and oscillograph apparatus has been developed by the Magnetic Analysis Corp., Long Island City, N. Y., for testing steel bars for defects. The principle of the apparatus is outlined. It is claimed that such defects in steel bars as cracks, seams, flaws, non-metallic inclusions and segregations may be detected with this magnetic testing equipment.—G. N.

Electro-magnetic Method of Detecting Cracks in Steel or Iron Parts Developed for Production Use in England. Automotive Industries, Vol. 62, April 19, 1930, pages 628-629.

Description and application of the s-called ExE electro-magnetic crack detector. Principle and application of the apparatus is outlined.—G. N.

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INSTRUMENT DESIGN AND CONSTRUCTION

A New Finish for Instrument Coils. C. B. Gordon-Sale. Instrument World, Sept. 1930, page 112

Application of artificial silk followed by a "dope" which partially dissolves the silk threads and bonds them.—M. F. B.

Temperature Coefficient of the Modulus of Rigidity of Aircraft Instrument Diaphragm and Spring Materials. W. G. Brombacher & E. R. Melton. Report 358. National Advisory Committee for Aeronautics, 16 pages.

Experimental data are presented on the variation of the modulus of rigidity in the temperature range—20 to 50°C. of a number of metals which are of possible use for elastic elements for aircraft and other instruments. The method of the torsional pendulum was used to determine the modulus of rigidity and its temperature coefficient for aluminum, duralumin, Monel metal, brass, phosphor bronze, coin silver, nickel silver, three high carbon steels, and three alloy steels. The temperature coefficient m is defined by the relation in which G and G_0 are the moduli of rigidity at the temperatures T°C. and O°C. The differential dG/dT was found to be a constant except for two metals. The effect of heat treatment on m was determined for a number of the materials. It was observed that tensile stress affected the values of the modulus by amounts of 1 per cent or less.

General Theory, Design and Construction of Sensitive Vacuum Thermopiles. C. Hawley Cartwright. Review of Scientific Instruments, Oct. 1930, pages 592-604.

Part I. A More Complete Theory of Vacuum Thermopile Design for N Junction for Four Types of Construction.

Attention is paid to the practical construction and application of the thermopiles. The sensitivity and quickness of reaching thermal equilibrium are both calculated by considering radiation from the receivers and conduction through the wires; the other factors are proved theoretically and experimentally to be negligible for designs found practical. In designing a thermopile for sensitivity, the whole galvanometer circuit has been considered. If we assume the approximate correctness of the Wiedemann-Franz Law, simple optimum conditions are obtained. Maximum sensitivity is found to depend on the sensitivities, resistances and characteristic of the galvanometers available and the size of the area into which the radiation to be measured can be concentrated. If it is impossible to concentrate the light into as small a receiver as can be made, the number of junctions to be used in series can be calculated. While the theory given is general, it is especially adapted to high thermoelectric power bismuth alloy wires at room temperature and for a critically damped galvanometer circuit. Curves are plotted to facilitate the best choice of a galvanometer and best design of a thermopile for use in many experiments. The formulas were verified experimentally at room temperature. Greater sensitivity was gained by having thermopile at the temperature of liquid oxygen, as predicted by the theory.

Part II. Construction of Sensitive Vacuum Thermocouples.

The vacuum thermocouples herein described had a sensitivity of about 1 V for 10^{-6} Cal. sec^{-1} falling on a receiver 0.5 mm^2 in area and reached practical thermal equilibrium in 0.1 sec. The sensitivity in vacuum was usually 20 to 40 times the sensitivity in air. Very short fine wires of high thermoelectric power, bismuth alloys, were soldered to a gold leaf receiver which was blackened on one side by electroplating it with platinum black. The lightness of the gold leaf receivers made the instrument extremely rugged.

Greater sensitivity was obtained for visible radiation by using a receiver of silver leaf tarnished on one side with H_2S; however, the sentivity decreased for wave lengths longer than 1.

RADIO TEST PANEL
Jewell Electrical Instrument Co.
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REFRACTOMETERS
Akatos, Inc.
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Spencer Lens Co.
REGULATORS—See Controls
RELAYS
General Electric Co.
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Claud S. Gordon Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
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Leeds & Northrup Co.
Westinghouse Elec. & Mfg. Co.
RESISTANCES—Electrical
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Spencer Lens Co.
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SACCHARIMETERS
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Bausch & Lomb Optical Co.
Spencer Lens Co.
Taylor Instrument Companies
SACCHROMETERS
Tagliabue Mfg. Co., C. J
SALINITY INDICATORS
Leeds & Northrup Co.
Rubicon Company
SCALES
Amthor Testing Instrument Co
Gaertner Scientific Corp.
H. Z. Schniewind
SCRATCH HARDNESS TESTER
SEISMOGRAPHS
Akatos, Inc.
SERVICE RECORDERS
Esterline-Angus Company
SHUNT METERS
SHUNTS
Esterline-Angus Company
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rubicon Company
Weston Electrical Inst. Corp.
SIGNALLING DEVICES—Automatic
Brown Instrument Co.
Stromberg Electric Co.
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SOIL PRESSURE CELLS
SPECIAL INSTRUMENTS
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Meriam Co.
H. Z. Schniewind
SPECIAL ELECTRICAL INSTRUMENTS
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Charles Engelhard, Inc.
Esterline-Angus Company
General Radio Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Rawson Electrical Instrument Co
Rubicon Company
Weston Electrical Inst. Corp.
SPECIAL RECORDING DEVICES
Esterline-Angus Company
SPECIFIC GRAVITY APPARATUS Gas.
American Meter Co.
SPECTROGRAPHS
Gaertner Scientific Corp.
SPECTROSCOPES
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
Spencer Lens Co.
SPECTROPHOTOMETERS
Akatos, Inc.
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
SPEED INDICATORS See Tachometers
SPEED RECORDERS
Esterline-Angus Company
STANDARD CELLS
Weston Electrical Inst. Corp.
STEEL TAPES
STOP WATCHES
American Meter Co
STRAIN GAGE
Southwark Fdry. & Mach. Co.
STRESS INDICATOR
STROBOSCOPES
Commercial Engg. Labs.
SULPHUR DIOXIDE METERS
American Meter Co.
Charles Engelhard, Inc.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
SULPHUR DETERMINATION APPARATUS
Burgess-Parr Co.
Tagliabue Mfg. Co., C. J.
SUNSHINE RECORDERS
Charles Engelhard, Inc.
Leeds & Northrup Co.
Taylor Instrument Companies
SUPERPRESSURE CATALYST EQUIPMENT
SURGE INDICATORS
General Electric Co.
SURGE RECORDERS
Esterline-Angus Company
General Electric Co.
SYNCHRONIZING FORKS—Electrical
General Radio Co.
Leeds & Northrup Co.
TACHOSCOPES
Brown Instrument Co.
TACHOMETERS
Amthor Testing Instrument Co.
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Foxboro Co.
Jewell Electrical Instrument Co.
Leeds & Northrup Co.
Pyrometer Instrument Company
H. Z. Schniewind
Herman H. Sticht & Company
Westinghouse Elec. & Mfg. Co.
Weston Electrical Inst. Corp.
TELESCOPES
Bausch & Lomb Optical Co.
Gaertner Scientific Corp.
TENSILE TESTERS FOR PAPER WIRE, SHEETS, ETC.
Amthor Testing Instrument Co.
H. Z. Schniewind
TENSIOMETERS
American Paulin System, Inc.
TENSOMETER (Huggenberger)
Southwark Fdry. & Mach. Co.
TESTERS, Gas
American Meter Co.
TESTING MACHINE—Universal
Claud S. Gordon Co.
H. Z. Schniewind
Southwark Fdry. & Mach. Co.
TEXTILE TESTING INSTRUMENTS
H. Z. Schniewind
THEODOLITES
THERMIONIC OXIDE RECTIFIERS
General Electric Co.
THERMO-JUNCTIONS (Electric)
General Radio Co.
Rawson Electrical Instrument Co
THERMOMETERS
Gas Filled
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Mechanical
American Meter Co.
Brown Instrument Co
Foxboro Co.
Tagliabue Mfg. Co. C. J
Mercurial
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Resistance
Brown Instrument Co.
Charles Engelhard, Inc.
Claud S. Gordon Co.
Leeds & Northrup Co.
Wilson-Maeulen Co., Inc.
Vapor-Tension
Bristol Company
Brown Instrument Co.
Foxboro Co.
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
Wet & Dry Bulb
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Leeds & Northrup Co.
Tagliabue Mfg. Co., C. J.
Taylor Instrument Companies
THERMOSTATS
Bristol Company
Brown Instrument Co.
Charles Engelhard, Inc.
Foxboro Co.
Claud S. Gordon Co.
Minneapolis-Honeywell Co.
Taylor Instrument Companies
Tagliabue Mfg. Co., C. J.
TIME OPERATION RECORDERS
Bristol Company
Esterline-Angus Company
Foxboro Co.
Claud S. Gordon Co.
Tagliabue Mfg. Co., C. J.
TIME RECORDERS
Bristol Company
Brown Instrument Co.
Esterline-Angus Company
Gaertner Scientific Corp.
Claud S. Gordon Co.
Foxboro Co.
TIME SWITCHES
General Electric Co.
Claud S. Gordon Co.
Westinghouse Elec. & Mfg Co
TIME STAMPS—Automatic
Stromberg Electric Co.
IME SYSTEMS—Electric
Stromberg Electric Co.

CALCULATIONS

Locating the Decimal Point in Slide Rule Calculations. Charles B. Irmer, Machinery, Feb. 1930 Page 455.

Discusses methods of locating the decimal point when calculations are made by slide rule. Gives equations to illustrate these methods. R. H. P.

Chart for Determining the Helix Angles of Screw Threads. I. H. Fullmer, Miscellaneous Publication No. 109, Bureau of Standards.

This chart shows graphically the relationships among diameters, leads, and helix angles of screw threads or other helical surfaces.

Electromechanical Scales for the Solution of Equations. (Eine elektromechanische "Gleichungswaage"). G. Rosen. Elektrotechnische Zeitschrift, Nov. 28, 1929, pages 1726-1727.

The author describes an electromechanical apparatus based on the resistance measuring principle which has for its object the solution of mathematical equations of higher degrees with one unknown quantity.—A. J. M.

A Ratiometer. W. A. Parlin, Review of Scientific Instruments, May 1930, pages 295-296.

A device for rapidly measuring the ratios of 2 graphically represented numbers such as the ordinates of 2 curves, is described.

MICROSCOPY

The Role of the Microscope in Research. E. R. Perry. Electric Journal, July 1930, page 427.

"In general, microscopic work takes advantage of both chemical and physical phenomena." Many applications of microscopic examination are mentioned.—W. H. B.

The Ultra-Violet Microscope. Francis F. Lucas. Bell Laboratories Record, Aug. 1930, pages 574-579.

As an offshoot of its development for metallography, the ultra-violet microscope has become available as a new tool for biological research. Not only does it give about twice as much detail as the best lens systems for visible light, but it largely obviates the need of staining the subject and it allows photographs to be taken at slightly different focal planes or levels, thereby giving a consecutive record of the architecture of the cells. Following the development of high power metallography and the utilization of the full potential resolving ability of the best apochromatic systems using visible light, Bell Telephone Laboratories arranged with the Zeiss Scientific Staff to design an ultra-violet microscope suitable for metallography and for transparent specimens. It soon became evident that a more exact method of focussing must be devised than the "searcher eyepiece" method of Kohler. Briefly, the focus must be exact to a hundred-thousandth of an inch. The additions which were made to the mechanical system of the microscope are described, as well as the method of operation by means of which it is possible to photograph the details of micro-organic structures on different planes within the transparent specimen. Magnifications of 3600 diameters or higher result in crisp, brilliant images with a degree of resolution surpassing by far that achieved with any other known optical system. It is interesting to learn from the article that ultra-violet light of the intensity and wave length used in conjunction with the ultra-violet microscope appears to have little if any harmful effect so far as many types of living cells are concerned. It is true that some single cell organisms are destroyed almost instantly; others of another species in the same mixed culture appear mildly excited and others immune.—M. F. B.

X-RAY TESTING AND EXAMINATION

The Application of X-Rays to the Study of Metals. James B. Friauf. Review of Scientific Instruments, July 1930, pages 361-396.

The 3 methods for the X-ray study of metals are considered: (1) the use of X-rays for the radiographic examination of metals, (2) the use of X-rays for the determination of chemical composition by the methods of X-ray spectroscopy, and (3) the use of X-rays for the study of the crystalline structure of metals. This latter method includes the determination of the crystal structures of the different constituents of alloys and the identification of the crystalline phases present in alloy systems, and the determination of orientation and grain size and the study of other properties of crystals, or crystal aggregates of known structure.

Testing of the Spectra from Two Commercial X-Ray Tubes for Purity (Die Prüfung der Spektrazweier technischer Roentgenelektronenroehren auf ihre Reinheit) K. F. Jahr, F. A. Schneider & A. Winkel, Zeitschrift fur physikalische Chemie, Jan. 1930, pages 256-260.

Two commercial X-ray tubes which were in service for a long period of time were checked for purity with the Seeman Spektrograph which yielded in both cases a spectrum absolutely pure. E. F.

The Application Possiblities of X-Ray Stereogrametry for the Location of Defects in Testing of Materials (Die Anwendungsmoeglichkeit der Roentgen-Stereogrammetric zur Fehlerortsbestimmung bei Materialuntersuchung). H. Wendt. Bildmessung und Luftbildwesen, Aug. 1930, pages 140-147.

By giving a proper shape to the anode surface Goetz succeeded in obtaining an almost point like source of the rays in the X-ray tube. Several kinds of such tubes are described and methods for evaluation of the pictures not only for relative, but also for absolute dimensions are given.—H. A.

"Self-Protected" X-Ray Tube. Electrical Review, July 25, 1930, page 159.

Description of the "Protexray" tube, of the hot-cathode type, designed by Cuthbert Andrews, London. It is furnished with a lead jacket surrounding the active zone of the tube, thus preventing the emission of X-rays, except by way of the working aperture.—M. S.

X-Ray Pearl-Testing Equipment. Electrical Review, July 11, 1930, page 77.

Description of an instrument developed by Jacob Vos in conjunction with Philips Lamps, Ltd. Consists essentially of a special "Metalix" X-ray tube mounted on adjustable legs. It is claimed to reveal immediately whether a precious stone is genuine or a pearl is cultured or imitation.—M. S.

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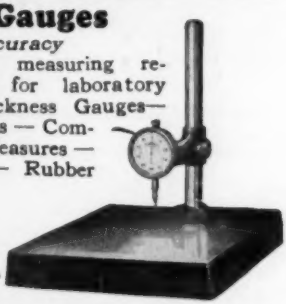

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M. F. BÉHAR, INSTRUMENTS, Vol. 3, No. 12, pages 729-774, figs.

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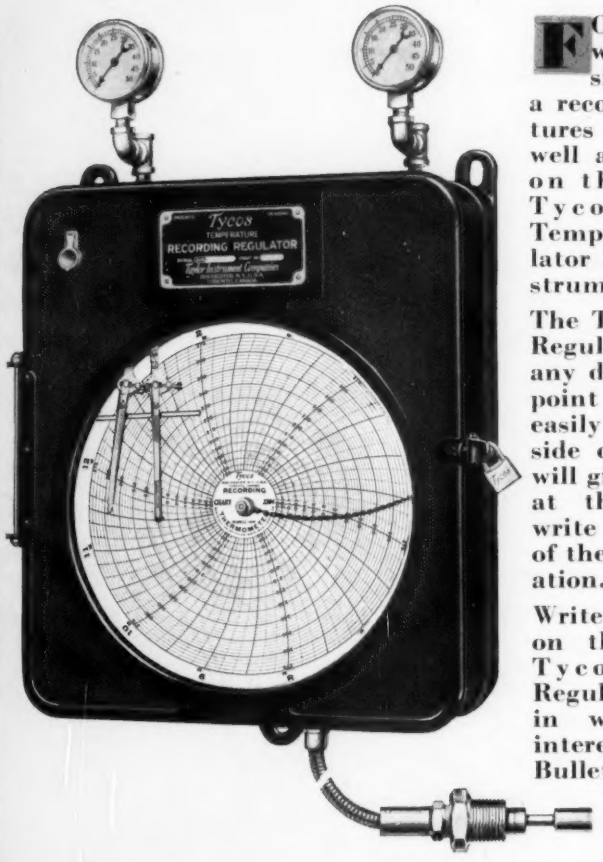

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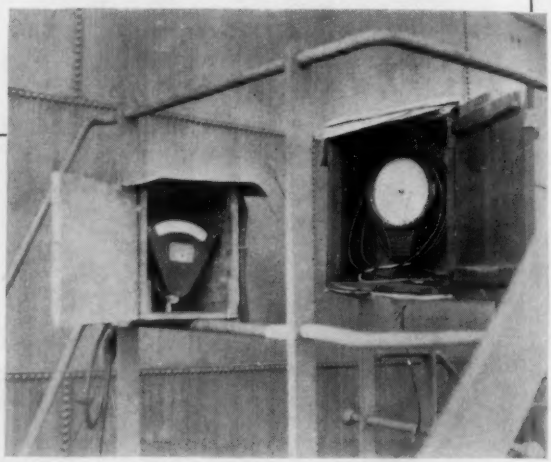

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